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THE

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EDITED BY

BENJ. APTHORP GOULD

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THE

ASTRONOMICAL JOURNAL.

No. 145.

VOL. VII. BOSTON, 1886 NOVEMBER 2. NO. 1.

PREAMBLE TO THE SEVENTH VOLUME.

The publication of the *Astronomical Journal* was discontinued in 1861, with great reluctance, yet with undoubting hope that the suspension would be not only temporary, but brief. In August, 1869, the arrangements for its reëstablishment had been fully matured, when they were interrupted by circumstances known to astronomers. The delays, thus occasioned, have been unexpectedly long, but, after the lapse of twenty-five years, all impediments seem to be at last removed, and no reason is apparent why the resumption may not now be regarded as permanent.

The plan is to continue the Journal in the same spirit as of old, and under essentially the same conditions. The chief of these are, that its object will be the advancement rather than the diffusion of astronomical knowledge, and that, while aiming at the promotion of harmony and cooperation among astronomers, laboring for a common end, it should afford opportunity for the expression of differences of opinion, founded upon research. It will thus be understood that the publication of an article implies no indorsement of the views which it may express, or of the accuracy of its statements.

The cordiality, and the inspiring offers of cooperation, with which the preliminary announcement of the reappearance of the *Astronomical Journal* has been received, call for an expression of grateful acknowledgement; and the kindly assurances of approbation and welcome, which have come in abundance, from both sides of the Atlantic, afford not only new incentives, but grounds for confident reliance upon the successful attainment of its desired ends.

Each volume will consist, as before, of twenty-four numbers, with a table of contents and alphabetical index. The numbers will appear at irregular intervals, and it is hoped that a volume will be completed as often as once a year. The price of subscription will be $5.00 in advance. The names of any agents, who may be appointed, will be announced hereafter; and in the meanwhile subscriptions may be sent to the Editor directly.

B. A. GOULD.

Cambridge, *Mass.*, *October*, 1886.

ON THE LIGHT-VARIATIONS OF SAWYER'S VARIABLE IN *VULPECULA*.

$20^h\ 45^m\ 19^s\ +27°\ 42'.3$, (1855.0)

BY S. C. CHANDLER, JR.

I beg to communicate the following investigation on the star DM. 27° 3890. The variability of this object, whose definitive designation will probably be *T Vulpeculae*, was discovered by Mr. SAWYER in October, 1885. From my observations of November and December of last year I found a period of $4^d.4368 = 4^d\ 10^h\ 29^m.0$. This value, communicated

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orally to Mr. SAWYER and by him published elsewhere, I now find, from a final discussion of all my observations to the present time, to require no appreciable correction, and we may accordingly adopt as the best attainable elements :—

$$1885 \text{ Nov. } 2.8576. \text{ Green. M.T.} + 4^d.4368\ E$$
$$= 1885 \text{ Nov. } 2^d\ 20^h\ 35^m \text{ Green. M.T.} + (4^d\ 10^h\ 29^m.0)\ E$$

for the epoch of maximum. The minimum is earlier by $1^d.060$.

The observed times of maxima and minima are here given. The column O—C is a comparison with the preceding elements.

OBSERVED MAXIMA.

E	Camb. M. T.	Wt.	O — C
			d
2	1885, Nov. 11.26	1	— 0.27
3	15.72	2	— .25
4	20.34	2	— .07
5	24.80	1	— .04
6	29.30	2	+ .02
7	Dec. 3.72	3	.00
9	12.72	1	+ .13
12	26.44	1	+ .54
13	30.29	1	— .05
14	1886, Jan. 3.74	1	— .03
17	17.26	1	+ .17
19	26.25	1	+ .29
40	Apr. 29.24	1	+ .11
44	May 16.88	1	.00
45	21.57	1	+ .25
59	July 22.74	3	+ .31
69	Sept. 4.52	1	— .28
70	9.34	2	+ .10
71	13.59	1	— .08
73	22.60	1	+ 0.05

OBSERVED MINIMA.

E	Camb. M. T.	Wt.	O — C
			d
2	1885, Nov. 10.91	1	+ 0.44
3	15.04	1	+ .13
6	28.31	3	+ .09
7	Dec. 2.33	2	— .33
8	7.03	2	— .06
9	11.56	1	+ .03
10	15.94	1	— .03
11	20.24	1	— .16
12	25.05	1	+ .21
13	29.32	3	+ .04
14	1886, Jan. 2.21	1	— .50
15	7.04	1	— .11
18	20.26	1	— .20
39	Apr. 23.13	2	— .50
41	May 2.38	2	— .13
42	6.86	2	— .09
45	20.74	1	+ .48
59	July 21.04	2	— .33
73	Sept. 21.40	1	— 0.09

These observed times were derived by applying to the time of each observation of the variable the correction indicated by the comparison of its observed light with the mean light-curve, or light-table, hereafter given. Values of $L > 11.0$ were used for deducing maxima, the others for minima. The weight column contains the number of observations combined to form each epoch.

From the residuals (O — C) it appears that the probable error of the time of a phase from a single observation of the variable, is $\pm\ 0^d.135$ for maxima, and $\pm\ 0^d.173$ for minima. It may be inferred that the probable error of an observed maximum or minimum, determined from two or more observations, is less than one tenth of a day.

The comparison-stars and the light-scale are

Star		1885.0 α	1885.0 δ	L	Mag.
		h m s	° ′		
a = DM.	27.3911	20 48 24	+27 30.0	18.0	5.27
b	25.4302	30 54	25 57.5	14.2	5.70
c	29.4131	34 36	29 17.5	10.0	6.17
d	31.4159	31 38	31 4.0	(11.5)?	
	31.4160	31 39	31 1.0		
e	31.4181	35 11	31 47.5	(10.0)?	
f	27.3909	48 13	27 58.3	4.6	6.80

The star *d*, being double in the field-glass and single to the naked eye, was used but a few times, and then rejected as unfit for use in the comparisons. The star *e* also, probably from some peculiarity of color or situation, has a varying aspect as to relative brightness, according as the field or opera glass, or the eye alone, is used. The values of *L* for both these stars are very uncertain, and I have consequently preferred to reduce the observations of the variable, using only *a*, *b*, *c* and *f*. In the last column I have added for convenience the approximate magnitudes in the usual (ARGELANDER'S) scale.

The formation of the mean light-curve was effected in the usual manner, all the observations being brought to bear, and using the period $4^d\ 10^h\ 29^m.0$. The characteristics of the light-fluctuations are a uniform and very rapid increase; a nearly uniform and very much slower decrease; a feeble indication of an undulation of the light-decrease — analogous to that which obtains in many other variables — which has however, been ignored in drawing the light-curve. The duration of increase is 1.060 days, and that of decrease is 3.377 days.

The readings of the light-curve give the following

LIGHT TABLE.

Time from Max.	L	Mag.	Time from Max.	L	Mag.
d			d		
— 1.06	7.0	6.55	+ 1.25	12.4	5.89
1.00	7.1	6.54	1.50	11.8	5.96
0.75	8.3	6.42	1.75	11.1	6.05
0.50	11.5	6.00	2.00	10.5	6.12
— 0.25	14.1	5.71	2.25	9.8	6.20
0.00	15.5	5.54	2.50	9.1	6.30
+ 0.25	15.2	5.58	2.75	8.4	6.40
0.50	14.5	5.66	3.00	7.7	6.48
0.75	13.8	5.74	3.25	7.1	6.54
+ 1.00	13.1	5.81	3.38	7.0	6.55

The range of variation is from $5^M.54$ to $6^M.55$. The va-

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riation during the greater part of the increase is at the rate of one and a third magnitudes a day; which is exceeded, I think, only by *U Geminorum* and a few stars of the *Algol* type. The decrease is at the daily rate of 0.35 mag., only. Observations made during the star's increase are therefore admirably adapted for determining the period with great precision.

Taking the difference between the observed light and that computed from the elements and light-curve, for each of the 57 observations, we get the sum of the squares of the residuals 42.89. Calling 6 the number of the arbitrary constants, we have $\pm$ 0.61 steps, or $\pm$ 0.067 mag., as the probable error of a single observation. This includes, besides the uncertainty of the observation itself, the effect of any departure from perfect regularity in the light-variations themselves, and of any errors in the period, etc. The mean deviation for the observations during the first month is $\pm$ 0.055, during the second month is $\pm$ 0.056, and for the remainder, $\pm$ 0.074. This shows that the probable error is not factitiously reduced by unconscious bias of the observer, since during the first weeks after discovery of variability, the knowledge of the law of variation, which might exert such a prejudicial influence, is entirely wanting.

The observations afford a hint of a phenomenon which has manifested itself in some other stars, namely, a greater range of discordance near minimum than near maximum. Thus the sum of the squares of the residuals for 18 observations within half a day of minimum is 20.29, while for an equal number within half a day from maximum it is only 4.79. Whether this is due to actual oscillation of the minimum brightness, or to subjective causes, must be decided hereafter. It may be due, in the case of this star, to the near equality of the variable at maximum with the comparison star *b*, which permits a nicer discrimination in the light-perception.

1886 September 22.

A NEW VARIABLE OF SHORT PERIOD.

$18^h\ 14^m\ 2^s$; $-18^\circ\ 54'.8$ (1875.0)

BY EDWIN F. SAWYER.

I beg to announce that I have discovered the star 57 (U. A.) *Sagittarii* to be a variable of short period. The star was first observed some four years ago (1882 September 5), in connection with my revision of a portion of the *Uranometria Argentina;* but no suspicion of its variability was entertained until 1886 September 22, on which date its faintness struck my attention. Observations on Sept. 24 and 29 fully established variability.

A preliminary reduction of my observations so far obtained indicates that the period cannot exceed six days. The range of fluctuation is from 5.6 mag. to 6.6 mag. In the field glass no trace of color can be discerned.

The comparison-stars used and the preliminary light-scale adopted are given below;—the positions being for the mean equinox of 1875.0.

In the *Uranometria Argentina* the star is 6.0 mag.

Uran. Argent.	α	δ	U. A. Mag.	Sawyer	Light Scale
	h m s	° ′			
65 *Sagittarii*	18 17 54	− 20 36.3	5.1	5.1	17.1
43 "	18 7 46	− 20 45.8	5.8	5.75	12.6
42 "	18 6 45	− 21 44.7	6.0	6.15	10.0
74 "	18 22 51	− 18 48.3	6.0	6.2	6.6
45 "	18 8 10	− 18 41.9	6.5	6.25	4.6
71 "	18 20 39	− 17 52.5	6.6	6.55	3.7
50 "	18 9 54	− 17 24.9	6.4	6.45	2.1

From the above light-scale the following light-values for the variable have been determined:

			h m	Light				h m	Light
1882,	Sept.	5	8 45	7.8	1886,	Oct.	7	7 0	8.4 :*
1886,		22	8 0	2.4			8	7 0	7.2 :*
		24	7 15	7.0			9	6 30	4.8 :*
		29	7 05	2.5			16	6 15	2.0
		30	6 45	11.8			19	6 10	7.5
	Oct.	1	7 0	11.6			20	6 10	4.9
		2	7 10	7.3			21	6 35	1.8
		3	6 30	5.2 :*					

* Moonlight.

Cambridgeport, Oct. 1886.

OBSERVATION OF THE SOLAR ECLIPSE OF AUGUST, 1886.

BY PROF. JOHN N. STOCKWELL.

The sun being hidden from the observatory, at the hour of the eclipse, by intervening buildings, I observed from the top of my house, using a transit-theodolite.

The instrument was made by Wurdemann and magnifies about 14 times. I did not succeed in observing the first contact, but obtained a very good observation of the time of last contact, as follows:

Local mean time of last contact, Aug. 28, $18^h\ 5^m\ 45^s.5$.

Longitude of station, $5^h\ 26^m\ 37^s$ W. from Greenwich.

Latitude, $+41^\circ\ 29'\ 47''$.

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ON THE INEQUALITIES OF THE MOON'S MOTION PRODUCED BY THE OBLATENESS OF THE EARTH.

By JOHN N. STOCKWELL.

PART I.

General Considerations and History of the Problem.

1. According to the law of universal gravitation, the attraction of a sphere upon an external point varies inversely as the square of the distance of the attracted point from the center of the sphere; and the motion of a body revolving about it is the same as if the whole mass of the sphere was collected at its center. In the case of an oblate spheroid, which differs but little from a sphere, analysis shows that the attraction upon a point situated within 35° 24′ of the equator is less than that of a sphere having the same mass; and for a point situated beyond that parallel the attraction is greater than for a sphere having the same mass.

2. The moon's orbit is so situated that it never recedes to a greater distance than 28° 35′ from the earth's equator; it is consequently always acted upon by a less force than if the earth were spherical. But since the attraction is least at the equator, and increases as the moon's declination increases, it follows that the attraction of the earth upon the moon depends not only upon its distance from the earth's center, but also upon its distance from the equator. It also depends upon the magnitude of the earth as well as its mass. The analytical expression of the attraction in the direction of the earth's center is composed of two terms, one of which is equal to the mass of the earth divided by the square of the distance of the attracted point; and the other varies as the product of its mass by a function of its figure, divided by the fourth power of the distance from the attracted point. The first of these terms produces the pure elliptic motion, and the second term produces the perturbations. A body revolving around the earth in a circular orbit, with the center of the earth as the center of force, would be subjected to a variable force unless the orbit were situated in the plane of the equator; in which case the motion would be free from inequalities, but less rapid than if the earth were spherical.

3. At the same time, the moon's motion is disturbed by the attraction of the sun; and in order to correctly calculate the place of the moon at any time, it is necessary to allow for the effects of both these disturbing forces. But in order to determine these disturbing forces with accuracy, it is necessary to know the correct values of the moon's coördinates, which are the very quantities we are seeking to find. Fortunately for our purpose, all these disturbing forces are very small with respect to the principal force which acts upon the moon; and we may in a first approximation calculate the effect of each force separately, as if the other had no existence. Sir John Herschel, in his *Outlines of Astronomy*, has very beautifully and truthfully translated into popular language the results of analysis as applied to problems of this character. He says, Art. (607): "From the extreme minuteness of the intensities of the disturbing, compared to the principal forces, and the consequent smallness of their *momentary* effects, it happens that we can estimate each of these effects separately, as if the others did not take place, without fear of inducing error in our conclusions beyond the limits incident to a first approximation. It is a principle in mechanics, immediately flowing from the primary relations between the forces, and the motions they produce, that when a number of very minute forces act at once on a system, their joint effect is the sum or aggregate of their separate effects, at least within such limits, that the original relation of the parts of the system shall not have been materially changed by their action. Such effects supervening on the greater movements due to the action of the principal forces may be compared to the small ripplings caused by a thousand varying breezes on the broad and regular swell of a deep and rolling ocean, which run on as if the surface were a plain, and cross in all directions without interfering, each as if the other had no existence. It is only when their effects become accumulated in lapse of time, so as to alter the primary relations or data of the system, that it becomes necessary to have especial regard to the changes correspondingly introduced into the estimation of their momentary efficiency, by which the *rate* of the subsequent changes is affected, and periods or cycles of immense length take their origin."

4. The history of our problem dates from the middle of the last century.* At that time the art of observation had been so far perfected that the moon's place in the heavens could be very accurately determined at any time; and a discussion of such observations led the astronomer Tobias Mayer to infer that there existed in the moon's motion in longitude, a small inequality depending on the longitude of the node, and having a period of nearly nineteen years. The coefficient of this inequality Mayer found to be only 4″; but as no sufficient cause for such an inequality was at that time known to exist, it was neglected by most astronomers. About thirty years after Mayer announced the existence of this inequality of long period in the moon's motion, Mason, by a discussion of a much more extended series of observations, found the coefficient of this inequality to be 7″.7, which was nearly twice the value found by Mayer.

LaGrange was the first to announce that the non-spherical

* The writer is indebted to Prof. A. Hall, of the Naval Observatory, for many points in the history of this interesting problem.

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form of the earth would affect the motion of the moon. This was in the year 1773; but he believed that the effects due to this cause would be insensible to observation, and he made no attempt to determine their theoretical value.

Towards the close of the last century LAPLACE discovered that the inequality depending on the longitude of the node of the moon's orbit was produced by the oblateness of the earth. He also found by calculation that the coefficient of the inequality should be about 6″.8, provided the oblateness of the earth was $\frac{1}{304.6}$, which was very nearly the value of the oblateness according to geodetical determinations. LAPLACE also found from theory that there should be an inequality in the moon's latitude arising from the same cause, and which was proportional to the sine of the moon's true longitude. This inequality in the latitude was found by theory to have a coefficient of 8″.0, and its period was about 27 days. No astronomer seems to have had the least suspicion of such an inequality in the moon's latitude, until its existence was made known by LAPLACE; and it seems very strange that an inequality in the longitude, amounting to only four or five seconds, and having a period of more than eighteen years, should be detected by astronomers, while a much larger inequality in the latitude — one which passes through all its values about thirteen times every year — should wholly elude their vigilance.

These investigations by LAPLACE were made about the close of the last century, and published in the third volume of the *Mécanique Céleste*, which appeared in 1802. He subsequently returned to the problem of these inequalities, and gave two additional solutions, one of which appeared in an appendix to the third volume in 1808, and the other was given in the sixteenth book, and fifth volume, of the *Mécanique Céleste*, which was published in 1825. In all these solutions of the problem, LAPLACE obtained identically the same values for the coefficients of the inequalities.

The problem of the perturbations of the motions of the heavenly bodies has been solved by two general methods. One of these methods consists in finding the perturbations of the *coördinates* of the disturbed body, directly from the forces; then applying these perturbations to the elliptical values of the coördinates, we obtain the true values of the coördinates at any assigned instant of time. The other method consists in finding the perturbations of the elements of the elliptical motion at any time, then applying these pertubations to the given elements, we are able to calculate the place of the planet in the same manner as if it were moving in a pure elliptical orbit. Modifications of these general solutions give rise to what are called special solutions. Either of these general methods is very useful in verifying the calculations made by the other.

After LAPLACE had made known the cause of these inequalities, other mathematicians investigated the same subject. Those who made a special study of the lunar theory were BURCKHARDT, DAMOISEAU, PLANA, PONTÉCOULANT, and HANSEN. All these investigators found essentially the same values for the coefficients as those previously found by LAPLACE.

In the years 1879-80 the writer busied himself a good deal with the lunar theory. He first determined the inequalities by the method of the variation of the coördinates, and then, in particular cases, verified them by means of the variation of the elements. When I attempted to deduce the inequalities arising from the oblateness of the earth, I was wholly unable to obtain the values found by other astronomers. I then attempted to verify my calculations by means of the variation of the elements, but without success. I found, however, that if I took the sum of the values given by the two solutions, I obtained the values found by other astronomers. I must admit, however, that I was unable to give any logical reason why the two solutions should differ from each other, nor why the sum of the two solutions should be equal to the value found by other astronomers. The theory of these inequalities was therefore in an unsatisfactory condition, and I had some misgivings about publishing them in that form, but trusted that time and further investigation would justify my course. I resumed the subject some three years later, and discovered what I conceived to be very serious errors in my own solution of the problem, and also in the solutions by other investigators. It is the object of the present communication to explain and rectify these errors.

In the autumn of 1884 a very remarkable paper by Mr. G. W. HILL on the subject of these inequalities was published by the *Nautical Almanac Office*. Former investigators had confined their attention to a few of the principal terms arising from the figure of the earth; but Mr. HILL with great perseverance and industry has carried his approximations to a very great extent, and has computed the values of nearly four hundred inequalities in the longitude and latitude of the moon. Of this vast number of inequalities there are only four in the longitude and five in the latitude, which have coefficients exceeding 0″.1 in magnitude; and these agree essentially with the results of other investigators; so that it seems a needless outlay of time and labor to extend the solution beyond a few of the principal terms.

In the *American Journal of Science* for February, 1885, I called attention to what seemed to me to be a serious defect in Mr. HILL's investigation; but Prof. J. C. ADAMS of Cambridge, England, has published a review of Mr. HILL's work, and also of my criticism, in the "*Observatory*" for March, 1886. In his review, Prof. ADAMS gives Mr. HILL's investigation his unqualified indorsement; so that it would seem that all the great astronomical authorities fully agree as to the correctness of the published solutions.

The most skilful analyst might therefore well hesitate to open a discussion upon a subject about which there is such unanimity of opinion; yet the importance of the problem seems to be a sufficient justification for so doing. I shall therefore first give what appears to me to be a correct solution of the problem, and shall then examine the solutions which have been given by other astronomers.

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ELEMENTS AND EPHEMERIS OF COMET 1886 *f*. (*BARNARD, OCT. 4.*)

From Professor FRISBY's observations of October 8, 10, and 12, I have computed the following approximate elements and ephemeris of the comet discovered by Mr. BARNARD on October 4. Middle place (O — C).

$$\delta\lambda \cos\beta = -9''.1$$
$$\delta\beta = -2''.0$$

$T =$ 1886 Dec. 14.4188, Gr. M.T.

$$\left.\begin{aligned} \omega &= 87^\circ\ 47'\ 1'' \\ \Omega &= 136\ 31\ 30 \\ i &= 103\ 50\ 58 \end{aligned}\right\} \text{Mean Eq. 1886.0}$$
$$\log q = 9.80014$$

Ephemeris for Greenwich midnight.

1886	α	δ	log r	log Δ	I
	h m s	° ′			
Nov. 1	11 50 25	+ 6 41.5	0.0329	0.1845	4.14
2	11 54 20	7 0.4			
3	11 58 24	7 20.0	0.0206	0.1691	4.70
4	12 2 36	7 40.2			
5	12 6 58	8 1.0	0.0081	0.1533	5.36
6	12 11 30	8 22.4			
7	12 16 13	8 44.4	9.9953	0.1371	6.12
8	12 21 8	9 7.1			
9	12 26 14	9 30.3	9.9822	0.1206	7.02
10	12 31 34	9 54.2			
11	12 37 7	10 18.5	9.9690	0.1038	8.06
12	12 42 55	10 43.4			
13	12 48 58	11 8.8	9.9556	0.0869	9.27
14	12 55 17	11 34.5			
15	13 1 53	+12 0.6	9.9420	0.0701	10.66

Light at discovery = 1.

U. S. Naval Observatory, Washington, Oct. 25. W. C. WINLOCK.

OBSERVATIONS OF *U OPHIUCHI*. 1885.

BY EDWIN F. SAWYER.

Owing to cloudy weather and sickness, only four minima of this star were observed during the year. The observed times (first column) have been deduced by ARGELANDER's method, using the mean light-curve formed from the 1883 observations. Besides the observed times of minimum so found, and given in the following table, a comparison is shown between the observed minimum and the elements given by CHANDLER in *Astr. Nachr.*, 2448.

Observed Minimum, Cambridge M. T.	Light Equation	Heliocentric Observed Time	Epoch	Comp. Time from Elements of Chandler	O – C
d h m	m	d h m		d h m	
1885 June 11 8 25.5	+ 7.6	June 11 8 33.1	1699	June 11 8 39.9	— 6.8
July 12 8 50.5	+ 6.4	July 12 8 56.9	1736	July 12 9 24.6	— 27.7
Sept. 2 9 15.5	+ 0.8	Sept. 2 9 16.3	1798	Sept. 2 9 21.6	— 5.3
Oct. 9 6 40.5	— 3.7	Oct. 9 6 36.8	1842	Oct. 9 7 0.1	— 23.3

The mean correction of the elements indicated by these observations is — 15^m.8, corresponding to the mean epoch 1769.

It will be interesting to collect the various determinations of the corrections afforded by all the observations to date. Thus we find:—

Authority	Observer	No. of Obs.	Mean Epoch	Correction to Elements
				m
A. N. 2572	Chandler	18	476, 1882 Aug. 20	— 1.7
2484	Sawyer	8	490, 1882 Sept. 1	— 3.3
2572	Chandler	11	882, 1883 July 27	— 3.0
2591	Sawyer	11	891, 1883 Aug. 3	—13.9
2660	"	5	1328, 1884 Aug. 4	+ 1.6
	"	4	1769, 1885 9	—15.8

These give a mean correction, giving weights according to number of observations, of — 5^m.2 for the mean epoch 802. From an unpublished discussion, which Mr. CHANDLER has made of all the observations of both observers in 1881 and 1882, he has found that there is a pretty certainly marked constant difference in the determination of time of minimum, Ch. — S. = 5^m.0. If we apply this, the mean correction to the elements will be — 7^m.7. These results would seem to indicate a correction to CHANDLER's period, of a trifle less than half a second of time. That is to say, the residual — 5^m.2 corresponds to a correction of his period by — 0^s.39, and the residual — 7^m.7, to a correction of — 0^s.59.

Cambridgeport, Mass., 1886 Sept. 25.

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ELEMENTS AND EPHEMERIS OF COMET OF *FINLAY*, (1886 *e*).

On October 2, by means of a rough computation of the elements of the comet recently discovered by Mr. FINLAY at the Cape of Good Hope, I called attention to their resemblance to those of DEVICO's comet (1844 I). There are, of course, some objections to the theory of identity between the two bodies, but it would beforehand readily be conceded that if the present comet is found to move in an orbit of comparatively short period, and with elements generally resembling those of that of 1844, the objections can have little weight.

I have accordingly embraced the first practicable opportunity to calculate more exact elements for the FINLAY comet. In Albany, notwithstanding our anxiety to secure observations, we have been able to do so in a satisfactory way on two occasions only—Sept. 29 and Oct. 22. Single comparisons were also obtained on Oct. 1 (ring-micrometer) and Oct. 16. The small inclination of the orbit of FINLAY's comet, as well as the unsatisfactory distribution of the few observations that have been made, determined me to compute the elements, using four instead of three dates; especially because Mr. EGBERT, who made the Albany determinations of position, regarded those of Oct. 1 and 16 as of little value in the coördinate of declination. In the computation, therefore, I have used the discovery-position as telegraphed, the observation at Nice, Oct. 1, combined with a ring-micrometer comparison by EGBERT (this latter half weight), a single filar-micrometer comparison by Mr. EGBERT, obtained Oct. 16, and an excellent filar-micrometer observation made by him on the evening of Oct. 22. By means of the orbit computed by me, Oct. 2, these observations were freed, so far as was then possible, from the effects of parallax and aberration and reduced to the equinox of 1886.0. As used in the computation, the observations were as follows:

G.M.T.	α 1886.0	δ 1886.0
Sept. 26.3261	255° 30′ 00″	—26° 04′ 14″
Oct. 1.2829	258 34 00	—26 18 57
16.5310	269 45 12	—26 39 11
22.4972	274 51 54.3	—26 31 54.0

Employing a method which neglects the intermediate latitudes, I have obtained the following elements:

$T =$ 1886 Nov. 19.8746. G.M.T.

$$\left.\begin{array}{ll}\pi & 14°\ 20'\ 24''\\ \Omega & 54\ \ 51\ \ \ 5\\ i & 2\ \ 49\ \ 53\end{array}\right\}\text{Ecliptic and Equinox of 1886.0.}$$

$$\begin{array}{rl}\log\sin\phi & 9.81165\\ \log a & 0.42383\\ \log\mu & 2.91426\\ \log q & 9.97022\end{array}$$

These elements indicate the remarkably short period of 4.32 years; yet it should be understood that the position of the comet with respect to the earth and sun is such that the observations will be fairly well satisfied with a much longer period and somewhat larger eccentricity. The place of Ω differs about ten degrees from that computed by BRÜNNOW for the comet of DEVICO; the above value of π is more than 30° greater than that of the 1844 comet; while the inclinations agree far within the errors of the present computation. The perihelion distance of the present comet is about one fifth less than that of DEVICO's. Yet these discrepancies are exactly what we should expect to see, because the very fact, that calculated returns of the 1844 comet have been looked for in vain, indicates that the elements of that comet have undergone material perturbations from some cause not yet explained. That cause may perhaps be found among the small planets.

The elements above given represent the extreme position exactly (or within the second, in each coördinate). The residuals (C—O) for the position of Oct. 1 are $\Delta\lambda$ $+1''$, $\Delta\beta$ $0''$; for the position of Oct. 16, $\Delta\lambda$ $+11''$, $\Delta\beta$ $-14''$. Roughly approximate comparisons with observations not used in the computation follow as indicated in the table; the signs are for C—O.

		$\Delta\alpha$	$\Delta\delta$
Sept. 29.	Rome	— 1″	— 3″
	Nice	— 8	—30
	Albany	— 7	— 9
	Nashville	—20	+ 1
Sept. 30.	Vienna	+ 4	— 9
Oct. 1.	Vienna	+ 7	— 1
	Rome	0	—15
	Nice	0	—15
	Albany	— 5	+29

Following is an ephemeris computed from the elliptic elements:

Greenwich 12h	α 1886.0	δ 1886.0	log Δ	Light
	h m s			
Nov. 1	18 57 34	—25 48.5	9.9212	2.2
3	19 5 45	25 34.1	9.9146	2.3
5	19 14 9	25 17.6	9.9077	2.4
7	19 22 45	24 58.7	9.9007	2.5
9	19 31 30	24 37.4	9.8936	2.7
11	19 40 26	24 13.4	9.8863	2.8
13	19 49 34	23 46.7	9.8789	2.9
15	19 58 53	23 17.2	9.8714	3.0
17	20 8 24	22 44.6	9.8639	3.1
19	20 18 6	22 8.9	9.8564	3.2
21	20 27 59	21 29.9	9.8489	3.3
23	20 38 4	20 47.4	9.8415	3.4
25	20 48 19	20 1.4	9.8342	3.5
27	20 58 45	19 11.7	9.8271	3.6
29	21 9 21	18 18.5	9.8202	3.7
Dec. 1	21 20 6	—17 21.7	9.8136	3.8

Dudley Observatory,
Albany, N. Y., 1886 Oct. 28.

LEWIS BOSS.

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OBSERVATIONS OF COMETS

MADE WITH THE 9.6 INCH EQUATORIAL AT THE U.S. NAVAL OBSERVATORY

BY PROF. E. FRISBY.

(Communicated by the Superintendent.)

1886 Washington M.T.	*	Number Comp's	☄ — * Δα	Δδ	☄'s apparent place α	log pΔ	δ	log pΔ
			COMET OF FINLAY.					
h m s			m s	′ ″	h m s		° ′ ″	
Sept. 30 7 26 16.5	1	17.4	−1 7.82	+9 2.8	17 12 19.87	9.543	−26 16 43.9	0.857
Oct. 1 6 52 12.4	2	20.4	+0 29.12	−0 5.9	17 14 50.71	9.470	−26 19 7.8	0.872
22 6 50 23.5	3	25.5	+1 53.20	+1 2.7	18 19 28.42	9.515	−26 31 52.2	0.864
23 7 12 58.5	4	15.3	+1 14.58	+9 37.0	18 23 7.34	9.559	−26 29 19.7	0.853
			COMET OF BARNARD.					
Oct. 7 16 55 7.9	5	20.4	+0 26.26	−6 40.4	10 42 9.32	*n* 9.637	+ 1 22 6.3	0.738
8 17 3 12.0	6	18.4	+0 22.23	−1 30.1	10 44 16.28	*n* 9.628	+ 1 31 16.7	0.737
10 17 3 57.7	7	15.3	+1 38.87	−6 45.9	10 48 34.82	*n* 9.623	+ 1 49 56.4	0.735
11 17 12 34.4	7	19.4	+3 53.48	+2 58.9	10 50 49.43	*n* 9.615	+ 1 59 41.2	0.734
12 17 2 40.1	8	20.4	+2 7.79	+2 16.2	10 53 4.23	*n* 9.623	+ 2 9 35.4	0.734

Adopted Mean Places for 1886.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	17 13 25.91	+1.77	−26 25 51.4	+4.7	Yarnall.
2	17 14 19.89	+1.70	−26 19 6.8	+4.9	Oe. Argelander.
3	18 17 33.52	+1.70	−26 33 2.6	+7.7	⅓(2 Yarnall + Argelander.)
4	18 21 51.08	+1.68	−26 39 4.4	+7.7	½(Yarnall + Argelander.)
5	10 41 42.22	+0.84	+ 1 28 53.3	−6.6	½(W. Bessel + Lamont.)
6	10 43 53.21	+0.85	+ 1 32 53.5	−6.7	"
7	10 46 55.10	+0.85	+ 1 56 49.1	−6.8	"
8	10 50 55.57	+0.87	+ 2 7 26.1	−6.9	"

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LIST OF NEBULAS OBSERVED AT THE LEANDER McCORMICK OBSERVATORY, AND SUPPOSED TO BE NEW.

No.	R.A. 1890.0	Decl. 1890.0	Mag.	Size	Form	Condensation.	No. of Obs.	Obsv'r	Notes
	h m	° ′							
1	0 10	—22 3	14.0	pS	iR, lE 120°	gbM	1	S	
2	0 10	14 7	14.0	0′.7	R		1	L	
3	0 19	14 35	15.5	0.2	R		1	L	
4	0 20	5 46	pF	vS	R	lbM	1	L	
5	0 25	13 58	14.5	0.4	R		1	L	
6	0 28	11 22	13.0	S	R	bsp	1	M	*12 P 90° Δ 3′.2
7	0 32	14 47	F	S	mE 0°	bM	1	S	Faint wing sp
8	0 33	15 16	F	S	mE 150°	bM	1	S	
9	0 34	14 51	eF	eS	E 60°	gbsbMN	1	S	
10	0 35	—19 14	12.0	vS	R	glsmbMN	2	L	
11	0 35	—14 24	15.5	0.8	pE 0°	lbMN	1	L	G.C. 107?
12	0 39	4 23	pF	pS	E 20°	bMN	1	L	*8, f 20ˢ
13	0 43	13 44	16.0	0.2	lE 30°		1	L	
14	0 47	13 46	16.0	0.5	R		1	L	1st of 4
15	0 47	13 46	16.0	0.5	R		1	L	2nd of 4
16	0 47	13 46	16.0	0.5	R		1	L	3d of 4
17	0 47	13 44	16.0	0.5	R		1	L	4th of 4
18	0 50	11 16	15.5	S	iR	gbM	1	M	*8, p 30ˢ
19	0 50	11 15	16.0	vS			1	M	Neb? f (18), P 75° Δ 1′.0
20	0 50	—17 16	16.0	vS			1	L	F*, p 40ˢ
21	0 54	—18 52	14.0	pS	pE	bnpN	2	L	
22	0 54	19 1	14.0	vS	R	sbMN	1	L	
23	0 59	17 9	16.0	eS	R		1	L	
24	1 0	18 24	vF	vS	R	gbM	1	L	
25	1 1	20 38	14.0	vS	vE	sbMN	1	L	
26	1 5	20 36	13.0	eS	R	sbMN	1	L	Neb?
27	1 16	16 57	15.0	vS	R		1	L	
28	1 20	18 46	13.2	vS	R		2	L	
29	1 20	20 32	13.0	vS	R	sbMN	1	L	
30	1 22	—18 46	14.0	pS	lE 0°	bMN	2	L	sev F st f in line n and s
31	1 23±	—10 51	15.0	vS	R		1	L	
32	1 27	17 7	12.5	pS	E 225°	glbM	1	L	
33	1 33	20 30	eF	vS	R		1	L	
34	1 35	18 25	vF	vS	vlE	sbMN	1	L	
35	1 36	13 36	15.5	0.1		gbMN	1	S	
36	1 44	27 58	14.0	1.3	R	gbM	1	S	
37	1 44	17 17	14.0	vS	R	lbMN	1	L	
38	1 47	13 22	16.0	0.4		gbMN	1	S	
39	1 49	17 5	vF	vS	R		1	L	
40	1 49	—11 21	14.5	pL	iR		1	M	*9, P 90° Δ 3′.6

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No.	R. A. 1890	Decl. 1890	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° ′							
41	1 50	—17 34	14.0	vS	R	bMN	2	L	*11, p 11^s
42	1 51	17 16	12.0	vS	R	bMN	2	L	env 14.0
43	1 51	9 27	11.5	0.4		gbMN	1	S	
44	1 52	9 31	13.0	1.6×0.4	E 65°	gbMN	1	S	
45	1 52	16 34	16.0	0.2	iR	gbM	1	S	
46	1 54	9 26	14.0	0.2	R	gbMN	1	S	
47	2 1	16 17	14.8	0.3	R	gbM	1	S	
48	2 1	16 21	15.8	0.1	R	gbM	1	S	
49	2 6	10 51	15.5	eS	E 325°	gbM	1	S	*10, n 1′.0
50	2 11	—18 19	vF	pS	vE 0°	gvlbM	3	L	sev vF st inv ; n end b?
51	2 17	—17 12	15.5	vS	R?		2	L	
52	2 20	16 20	15.0	0.4	R	gbM	1	S	
53	2 23	11 19	13.0		R		1	M	neb* *?
54	2 23	11 18	13.5		R		1	M	
55	2 23	15 1	15.0	0.4	vE 0°	sbN like a *	1	L	
56	2 23	10 59	15.0	0.7	R	gbM	1	S	
57	2 24	11 31	15.0	0.4		gbM	1	S	
58	2 27	19 8	14.5	S		gbM	1	S	
59	2 28	11 27	15.0	0.4		gbM	1	S	
60	2 30	—17 0	13.0	vS	R	bMN	3	L	
61	2 34	—11 30	15.0	0.4			1	S	neb? in same field with G.C. 5262 and 5263
62	2 34	16 17	13.5	vS	lE 0°?	lbM	2	L	2 B st, p 20^s
63	2 38	16 46	15.5	vS	R		1	L	
64	2 38	16 41	14.0	vS		bMN	1	L	
65	2 41	18 1	13.0	vS	R	sbMN	1	L	
66	2 41	18 1	13.5	vS	R	sbMN	1	L	
67	2 42	18 9	12.0	vS	R	glsbMN	1	L	1st of 3
68	2 42	18 11	13.0	pS	lE 0°	slbMN	1	L	2nd of 3
69	2 42	18 10	12.5	vS	lE 30°	sbMN	1	L	3d of 3
70	2 42	—16 35					1	L	same as (64)?
71	2 43	—16 10	14.5	vS	R		1	L	
72	2 45	18 29	12.0	eS	R		1	L	*?
73	2 45	14 55	14.0	0.5	R	gbsbMN	1	L	env 14.5
74	2 46	26 10	16.0	eeS	iR	gbM	1	S	*9, nf 1′.0
75	2 49	14 58	14.0	0.3	R	gbMN	1	L	env 15.0
76	2 52	15 29	14.0	0.4	R	sbMN	1	L	env 15.0
77	2 52	15 27	16.0	0.4	R		1	L	neb? in same field with (76)
78	2 53	15 34	15.0	0.7	E 0°	sbMN	1	L	env 16.0
79	2 53	14 49	15.0	0.4	R	sbMN	1	L	env 15.5
80	2 54	—17 37	vF	pS	vE 75°	bnp	1	L	spindle shaped
81	2 57	—19 20	15.5	pS		gbM	1	S	*12 f 1′.0
82	2 57	15 27	15.0	vS	R	bMN	1	L	env 16.0
83	2 57	15 29	15.0	vS	R	bMN	1	L	env 16.0
84	2 57	10 6	15.5	0.7×0.3	E 120°		1	S	*10, P 240° Δ 2′.5
85	3 0	14 48	14.0	0.3	R	bMN	1	L	neb? env 14.5
86	3 0	12 46	15.5		E 45°		1	L	B* and sev F st inv in neb, r
87	3 0	10 7	14.0	0.7×0.3	E 25°		1	S	*9.5, P 240° Δ 3.′0
88	3 1	26 10	15.0	vS	iR, E 340°?	gbMN	1	S	
89	3 1	15 56	15.0	vS	R		1	L	
90	3 1	—16 2	15.5	vS	R		1	L	1st of 5
91	3 1	—16 5	15.5	vS	R		1	L	2nd of 5
92	3 1	16 7	15.5	vS	R		1	L	3d of 5
93	3 1	16 6	15.5	vS	R		1	L	4th of 5, 5th is G.C. 648
94	3 2	9 58	14.0	0.7×0.2	E 60°		1	S	48^s = f G.C. 647 same decl. stell N in cen of vF neb ; 1st of 3 ; *10, P 15° Δ 3′.0.
95	3 2	10 3	15.5	0.4		dif	1	S	2nd of 3
96	3 2	10 2	14.5	0.2		stell	1	S	3d of 3
97	3 5±	—16 0	16.0	pL	E like fan		1	L	neb?

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No.	R. A. 1890.	Decl. 1890	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° '							
98	3 8	—26 10	15.5	4.1×2.0	E 315°	vgbsbMN	1	S	
99	3 10	16 18	15.0	pS	iR	sbMN	1	L	env 15.5
100	3 10	—15 31	14.0	0.7	lE 0°	sbM	1	L	env 16.0
101	3 13	—14 23	15.8	0.1			1	S	near (102)
102	3 14	14 24	15.0	0.2		gbMN	1	S	*10, P 75° Δ 3′.0
103	3 15	18 57	13.0		iF, vmE 135°		1	S	
104	3 16	25 56	14.8	vS		gbM	1	S	no N, * 10.5, f 4′.0
105	3 20	26 4	16.3	vS			1	S	neb?
106	3 30	25 18	13.0				1	S	*9, nf 5′.0
107	3 30	16 4	14.0	vS	R	lbM	1	L	
108	3 31	16 16	14.0	vS	R	glbM	1	L	
109	3 33	16 17	14.5	vS	R	lbM	1	L	
110	3 35	—15 53	16.0	pL	vE 150°	glbM	1	L	sev vF st inv
111	3 36	—15 57	15.0	vS	R	lbM	1	L	
112	3 40	23 21	15.0		vmE 60°	N	1	S	*10, f 1′.0
113	3 40	9 33	16.0	0.8		stell N	1	S	D, P 310° Δ 0′.4
114	3 40	9 33	16.0	0.8		stell N	1	S	
115	3 42	25 52	15.0	pS		gbM	1	S	
116	3 48	15 44	14.5	vS	pE 45°		1	L	
117	3 48	8 54	14.0	0.1		stell N	1	S	1st of 3
118	3 49	8 54	15.0	0.2			1	S	2nd of 3
119	3 49	8 52	15.0	0.2			1	S	3d of 3
120	3 57	— 9 38	16.0	0.2	R	gbM	1	S	
121	3 57	— 9 37	15.3	0.3	R	gbM	1	S	
122	3 59	11 28	14.0	0.1	R	gbM	2	S	
123	4 5	9 5	16.0	0.7	R	gbMN	1	S	D, P 340° Δ 0′.5
124	4 5	9 5	16.0	0.7	R	gbMN	1	S	
125	4 10	13 31	16.0	0.1	R	gbM	1	S	
126	4 13	18 9	pF	pS	iR		1	L	cl? or neb with sev vF st and one * 11.5 n of cen inv
127	4 18	16 7	14.0	vS	lE 170°	glbM	1	L	*8, p 6ˢ
128	4 18	16 2	14.5	eS	R	glbM	1	L	
129	4 18	16 0	15.5	vS	R	lbM	1	L	D
130	4 18	—16 0	15.0	vS	R	lbM	1	L	
131	4 18	—16 2	16.0	pS	lE		1	L	
132	4 24	17 52	12.5	vS	R	sbMN	1	L	env 13.0
133	4 24	17 47	12.5	eS	R	sbMN	1	L	env 14.0
134	4 26	11 31	15.5	0.2	R	gbM	2	S	
135	4 31	13 46	15.8	0.2	R	gbM	1	S	
136	4 36	20 38	14.0	0.4	E 40°	gbMN	1	S	
137	4 40	16 6	13.0	pS	E 0°	glsmbMN	1	L	env 14.0
138	4 47	15 32	15.5	vS	vE 30°		1	L	
139	4 49	20 44	15.0	0.2	R		1	S	
140	4 53	—15 28	13.0	vS	R	glsbMN	2	L	env 13.5
141	4 55	—16 0	12.0	vS		sbMN	2	L	D, P 110° Δ 10″
142	4 55	16 0	12.0	vS			2	L	
143	4 56	18 19	14.0	0.4	E 45°		1	S	
144	4 56	18 19	15.0	0.2	E? 90°		1	S	in same field with (143)
145	5 0	19 36	15.0	0.1		gbM	1	S	
146	5 2	18 19	14.5	0.1		gbM	1	S	
147	5 6	15 15	14.0	vS	lE 140°		1	L	
148	5 20	16 4	15.0	pS	pE 0°	glbM	1	L	
149	5 28	14 12	15.0	pS	R	bMN	1	L	env 15.5
150	6 14	—18 29	14.0	pS	E 45°	glsbMN	1	L	
151	6 14	—18 29	15.5	vS	R		1	L	in same field with (150)
152	8 43	13 53	16.0	0.4			1	S	neb?
153	8 49	— 4 34	15.8	0.2		stell	1	S	

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No.	R.A. 1890	Decl. 1890	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° ′							
154	9 22	—14 3	15.0	0.3	R	bMN	1	L	env 15.5
155	9 26±	+31 36±					1	S	found while looking for Winnecke's comet
156	9 33	—11 56	15.0	1.1	iR	gbM	1	L	
157	9 37	16 9	eeF	S	R	gbM	1	S	
158	9 43	5 59	eF	vS	R		1	L	
159	9 50	11 57	15.5	1.2	D or bi N		1	L	tri N?
160	9 51	—25 11	14.5	2.7×0.8	E 120°		1	S	16.5 vgb 16.0 vsb MN
161	9 51	— 5 51	16.0	vS	E 45°		1	L	
162	9 54	5 54					1	L	same as (161)?
163	9 59	20 15	15.0	0.1	R		1	S	neb?
164	10 2	15 36	16.0	1.6×0.7	vE 45°		1	L	
165	10 2	15 36	16.0	1.3×0.7	vE 170°	lbN	1	L	
166	10 4	16 6	15.5	0.5	R	sbMN	1	L	
167	10 4	16 6	16.0	0.3	R		1	L	
168	10 6	20 20	15.0	0.4	R	gbM	1	S	
169	10 9	20 5	15.5	0.4	R	gbM	1	S	
170	10 10	—18 29	16.0	0.8	iR		1	S	neb?
171	10 14	—25 16	15.8	1.6	iR	gbM	1	S	
172	10 18	21 42	16.0	1.6	spiral?	stell N	1	S	N 0′.1, env 16.0
173	10 30	12 5	15.0	1.6			1	L	D neb or sev st inv in neb
174	10 30	12 9	15.0	0.7	R	gpmbM	1	L	
175	10 30	12 7	15.5	0.5	iR	gbMN	1	L	
176	10 32	24 45	15.5	0.1	R	gbM	1	S	*15, n 3″.0
177	10 41	24 40	16.0	0.2	R		1	S	
178	10 50	20 30	15.0	1.3×0.4	E 125°		1	S	
179	10 52	19 3	15.5	0.4	R	gbM	1	S	
180	10 53	—14 22	15.5	0.6	E 90°	gbMN	2	S	
181	10 57	—14 22	16.0	1.2	iR	glbM	1	L	
182	10 59	5 58	15.0	0.1	lE 110°		1	S	in same field with neb disc by Stephan
183	11 1	18 52	12.0	0.8		gbMN	1	S	
184	11 4	17 41	14.0	2.5×0.4	E 95°	gbsbgbM	1	S	G.C. 2330?
185	11 5±	19 27	vF	vS	R	gbMN	1	S	1st of 2
186	11 5±	19 27	eeF	eS	R	gbM	1	S	2nd of 2
187	11 24	8 1	15.0	0.2		gbMN	1	S	
188	11 25	2 37	14.5	0.3	R	gbM	1	S	
189	11 25	2 39	16.0	0.1			1	S	
190	11 33	— 2 48	15.0	0.2		gbM	1	S	
191	11 33	—11 57	15.0	0.8	iR	glbM	1	L	S* or neb f
192	11 44	9 7	15.5	1.8	iR	gbM	1	S	
193	12 8	11 58	15.8	0.8			1	S	
194	12 54	13 32	16.0	0.3	R		1	L	
195	12 54	13 27	15.5	0.3	vE 45°	sbMN	1	L	
196	13 8	18 58	14.0	1.6×0.2	E 30°	gbM	1	S	8′ f G.C. 3448 P 110°
197	13 13	9 38	15.0	0.2			1	S	
198	13 19	9 37	14.0	0.2		gbM	1	S	
199	13 53	13 37	12.0	S	R	vgbM	1	M	
200	13 57	—14 4	F	pS	vE	gbp	1	L	a little curved, shades off gradually like a comet's tail; no N seen
201	14 8	—17 27	14.0	0.4	R	gbM	1	S	*13 in field
202	14 14	18 37	14.0	0.7	iR	gbMN	1	S	
203	14 27	16 6	16.0	0.2	R	glbM	1	L	
204	14 27	14 6	pF	S	E	gbM	1	L	
205	14 36	17 58	12.8	0.3	R	gbM	2	S	*10.5, np 2′.7
206	14 38	20 25	vF	S	lE	glbM	1	L	
207	14 39	11 28	14.0	vS	R	sbMN	1	L	
208	14 39	11 22	12.0	pS	pmE	gbMN	1	L	env 15.0
209	14 39	20 25	F	S	vE	smbMN	1	L	
210	14 39	—18 1	15.5	0.2			1	S	neb?

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No.	R.A. 1890	Decl. 1890	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° ′							
211	14 43	−19 49	14.5	0.3	R	glbMN	1	L	
212	14 46	20 55	eF	1.0	R	gbM	1	S	
213	14 53	16 14	15.4	0.8×0.3	lE 135°	bMN	2	L	
214	14 53	16 10	12.8	0.8		gbsmbMN	2	L	N almost stell
215	14 54	13 25	vF	vS		sbM	1	L	1st of 3
216	14 54	13 26	vF	vS		sbM	1	L	2nd of 3 brightest and most nebulous of the three
217	14 54	13 24	vF	vS		sbM	1	L	3d of 3
218	14 55	17 25	eF	vS	lE 230°		1	S	bet 2 vFst
219	14 56	16 23	15.0	0.8	E 10°		1	L	F$*_*$? inv in neb $*_*$ on p side of neb
220	14 56	−15 42	11.0	0.8		gbMN	1	S	stell
221	14 56	−15 46	14.0	0.8			1	S	sev F st in field
222	15 1	14 8					1	L	* 13.0 inv in vF neb 3st, p 1^s.0; *8.0 f 10^s.0 15′.0 s
223	15 4	18 0		S	R	gbMN	1	S	*12 in eF neb
224	15 8	14 8	15.2	0.2	R	lbsbMN	2	L	in field with Harv. 331
225	15 10	17 9	vF	vS	E 235°		1	S	
226	15 10	11 7	13.0	pS	lE	gbM	1	L	*11, f
227	15 10	14 35	16.0	2.5		gbM	1	S	
228	15 31	16 13	14.5	pS	vlE?	glsbMN	2	S	
229	15 36	12 52	eF	vS		sbMN	1	L	in a group of st
230	18 2	−29 34	vF	vS	R		1	L	rr
231	20 26	−25 51	13.2	pS	R	sbMN	2	L	*; n 1′.0, neb * in field?; env 14.0
232	20 28	11 46	15.0	0.6×0.2	E 120°	gbM	1	L	divided into 2 parts?
233	20 30	25 40	13.8	vS	R	slbMN	2	L	env 14.0
234	20 50	11 30	16.0	0.2	iR		1	L	
235	20 50	19 0	14.0	vS	R	glbMN	2	L	
236	20 53	26 7	14.0	vS	R	sbMN	1	L	env 15.0
237	21 1	25 56	14.0	eS	R	bMN	2	L	1st of 3
238	21 1	25 56	15.0	vS	R	bMN	2	L	2nd of 3
239	21 1	25 54	vF	vS	vlE	glbM	2	L	3d and b of 3
240	21 1±	−24 51	15.0	vS		sbMN	1	L	
241	21 4	−20 57	14.0	vS	iR	sbnMN	1	L	
242	21 35±	10 50	11.0	vS	E 310°?	smbMN	1	L	*n, P 310°
243	21 38	25 52	vF	pS	vE 90°		3	L	like comet with tail; 2 st inv
244	21 50	25 54	14.0	vS	R	sbMN	1	L	B$*_*$, p 8^s; env 16.0
245	21 55	5 59	13.0	pS	iR	bMN	2	L	$*_*$p 36^s
246	21 57	33 19	pF	pS	R	lbM	1	L	
247	21 57	20 52	eF	pS	E	lbM	1	L	
248	22 12	24 17	pF	vS	R	gvlbM	1	L	B$*_*$ p 13^s, F$*_*$, f 5^s
249	22 16	16 7	16.0	2.5×0.5	vE 30°	sbMN	1	L	
250	22 19	−13 46	eF	pS	R	glbM	1	L	
251	22 24	−25 59	vF	vS	R		1	L	
252	22 26	18 9	vF	pS	lE 0°	lbM	1	L	
253	22 28	13 33	pB	vS	R		1	L	no * in field
254	22 29±	23 5	15.0	pS	R	bMN	1	L	
255	22 33±	23 16	pF	pS	E	lbM	1	L	
256	22 38	24 17	pF	vS	pmE	bMN	1	L	
257	22 39	20 32	14.5	eS	R	gbMN	2	L	*11, nf 4′.0; neb *
258	22 43	20 20	eF	vS	R	gbM	1	L	
259	22 51	11 32	15.5		lE? 90°		1	M	*10, P 260° Δ 4′.0
260	22 54	− 7 38?	14.0	0.8	iR		1	S	*10, p
261	23 0	−20 32	14.0	vS	R	gbM	1	S	
262	23 13±	7 31	13.5	pS	lE 180°	lbMN	1	L	
263	23 20	19 41	vF	vS	R	bMN	1	L	
264	23 33	23 36	eF	vS	R		1	L	
265	23 37	20 4	15.0	eS		gbM	1	S	bet 2 st 12
266	23 42	17 14	16.0	vS			1	L	
267	23 43	−17 10	14.0	vS	R		1	L	

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No.	R.A. 1890	Decl. 1890	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
268	23^h 44^m	−14° 0′	13.0	vS	R	gbM	1	S	* 10, p 8′.0
269	23 45	17 13	15.0	vS	R		1	L	F * f
270	23 47	−14 0±	15.0	vS	lE 315°	gbM	1	S	near (268)
271	23 56	−19 23	16.0	pS	iF E 90°?		1	S	
272	23 56	11 21	15.0	vS	R	stell N	1	M	* 8.5, P 240° Δ 3′.6
273	23 59	−17 6	14.0	pS	iF E 125°	glbM	2	S	

S = Ormond Stone; L = F. P. Leavenworth; M = Frank Muller; env = envelope; P = position angle; Δ = distance; other abbreviations as in *Herschel's general catalogue.*

In the earlier observations *Herschel's abbreviations* were used to designate brightness and size. Afterwards numerical magnitudes were employed to indicate brightness, assuming that the faintest nebula visible in the 66^{cm} refractor, with power 167, is 16.3, that being the theoretical limit for stars. The magnitudes given refer to the nucleus, or, in case there is no nucleus, to the brightest part. Still later the custom was instituted of estimating the diameters of the nebulas observed in fractions of the diameter of the field, and from these deducing their dimensions in minutes of arc.

Sketches have been made of the larger portion of the nebulas contained in this list.

ORMOND STONE.

University of Virginia, 1886 *October* 12,

LATITUDE OF THE SAYRE OBSERVATORY.

By Prof. C. L. DOOLITTLE.

During the years 1876–77 I made a somewhat extended series of observations with the Zenith-Telescope for determining the latitude of our observatory. A few observations were also made in the spring of 1878; the mean date of the series being 1877.17.

Sixty pairs of stars were employed; the number of observations was 459, an average of 7.65 per pair.

Sixty-two of the stars were taken from Boss's Catalogue of 500 stars, the remaining 58 were reduced by myself, nearly all the data to be found in the library of the U. S. Naval Observatory being employed. Boss's systematic corrections were applied in order to make the entire series of declinations homogeneous. The results of this work were published in the *Astronomische Nachrichten*, No. 2260.

In September, 1885, I began a series of observations for redetermining the latitude, and the observations were finished August, 1886. The mean date was 1886.12. The stars employed were the same as in the previous determination, with the exception of three pairs, which for different reasons were not available. This series comprised 288 observations of 57 pairs, an average of 5.1 per pair.

The observations were all made by myself, the same instrument being used throughout. The level-tube was twice refilled during the interval between the two series; otherwise nothing was done by way of change or repair. As the instrument was used more or less every year by the students of the University, there must have been some wear of the parts. The precision of the observations comprising the latter series was however a little greater than of the former, therefore no great deterioration could have taken place.

Taking the results of the earlier series, and using only those stars which were employed in the latter, 57 equations were written, of the form

$$\Delta\varphi - \tfrac{1}{2}(M - M')\,\Delta R = \varphi - \varphi'$$

each pair of stars giving one equation.

$\Delta\varphi$ is the correction to the assumed latitude φ'.

ΔR, the correction to the assumed value of the micrometer-screw.

The results were as follows:

$$\begin{aligned} \varphi_1' &= 40^\circ\ 36'\ 23''.887 \\ \Delta\varphi_1 &= \qquad\quad +.018 \pm .037 \\ \varphi_1 &= 40\ \ 36\ \ 23.905 \pm .037. \end{aligned}$$

In the same manner the second series gave the following results:

$$\begin{aligned} \varphi_2' &= 40^\circ\ 36'\ 23''.530 \\ \Delta\varphi_2 &= \qquad\quad -.018 \pm .051 \\ \varphi_2 &= 40\ \ 36\ \ 23.512 \pm .051. \end{aligned}$$

Therefore $\varphi_1 - \varphi_2 = 0''.393 \pm 0.063$.

If we regard only those parts of the probable errors of φ_1 and φ_2 which are independent of the declinations of the stars employed, we find for the probable error of the difference, viz: $(\varphi_1 - \varphi_2)$, $r = .045$.

The following tabular statement exhibits the values of the latitude, as given by each pair of stars employed. If we

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take the arithmetical mean of the quantities in the column headed $(\varphi_1 - \varphi_2)$, giving all equal weights, we have

$$(\varphi_1 - \varphi_2) = 0''.374 \pm 0''.044.$$

This result is practically identical with the preceding.

φ_1 1877	φ_2 1886	$\varphi_1-\varphi_2$	φ_1 1877	φ_2 1886	$\varphi_1-\varphi_2$	φ_1 1877	φ_2 1886	$\varphi_1-\varphi_2$	φ_1 1877	φ_2 1886	$\varphi_1-\varphi_2$
40° 36′	40° 36′		40° 36′	40° 36′		40° ′36	40° 36′		40° 36′	40° 36′	
″	″	″	″	″	″	″	″	″	″	″	″
23.24	23.43	−0.19	24.62	24.01	+0.61	24.27	23.71	+0.56	24.09	22.81	+1.28
23.83	23.90	−0.07	23.55	22.46	+1.09	24.04	23.37	+0.67	23.80	23.29	+0.51
23.72	23.39	+0.33	24.03	22.48	+1.55	24.01	23.22	+0.79	24.26	23.40	+0.86
24.25	23.56	+0.69	23.76	23.64	+0.12	24.52	24.24	+0.28	24.60	24.24	+0.36
24.16	23.83	+0.33	23.82	23.08	+0.74	24.13	23.78	+0.35	24.73	24.79	−0.06
23.24	23.53	−0.29	23.68	23.59	+0.09	23.61	23.22	+0.39	24.02	23.26	+0.76
23.45	23.02	+0.43	23.97	23.37	+0.60	24.25	24.29	−0.04	23.90	23.74	+0.16
23.57	23.29	+0.28	23.26	22.81	+0.45	24.16	24 06	+0.10	23.97	23.40	+0.57
23.58	23.60	−0.02	23.37	24.15	−0.78	24.34	23.97	+0.37	23.29	23.33	−0.04
23.38	22.95	+0.43	23.44	23.17	+0.27	23.07	22.43	+0.64	24.41	24.70	−0.29
24.23	23.98	+0.25	24.05	24.75	−0.70	23.43	23.82	−0.39	23.81	23.40	+0.41
23.82	23.09	+0.73	24.41	24.36	+0.05	24.05	24.36	−0.31	23.39	23.29	+0.10
23.71	22.55	+1.16	25.12	23.89	+1.23	24.05	23.45	+0.60	Mean = 0.374		
23.72	22.68	+1.04	23.60	24.16	−0.56	23.64	23.37	+0.27	± 0.044		
24.32	23.59	+0.73	24.30	22.96	+1.34	23.87	23.37	+0.50			

The results are given for what they may be worth, the interpretation of the evidence for or against a change of latitude being left to the judgement of the reader.

Lehigh University, S. Bethlehem, Pa.

ELEMENTS AND EPHEMERIS OF COMET OF *FINLAY*, (1886 *e*).

By Rev. G. M. SEARLE.

I have computed the following elements for Finlay's comet, on the assumption of a period of 5.278 years, giving 8 revolutions since 1844. The observations used were the discovery-observation of September 26, that by Mr. Egbert, at Albany, on October 16, and a comparison which I obtained with ψ *Sagittarii* on Nov. 4. This last gave for 1886.0

	α	δ
Nov. 4.492 G.M.T.	$19^h\ 9^m\ 37^s.0$	$-25°\ 28'\ 2''$

Two hypotheses were made for M, the ratio of the curtate distances, and one interpolated to agree in longitude with the middle place. The resulting elements are

T	Nov. 21.909. Greenw.M.T.	
☊	53° 47′ 48″	1886.0
π	10 51 22	1886.0
i	2 57 29	
$\log e$	9.83294	
$\log q$	9.98588	
$\log a$	0.48164	
$\log \mu$	2.82755	

They represent the middle place as follows:

O — C

$\Delta\lambda$	$\Delta\beta$
+ 6″	+ 15″

and seem to be about the best representation that can be made of it with the assumed period; but as the observation of October 16 is not considered by Mr. Egbert of much value in latitude, and as that of November 4 was also only rough, it would be useless to attempt to deduce any period from the materials used.

These elements give the following ephemeris for Greenwich midnight; the unit of light is that at the time of discovery.

Date	α 1886.0	δ 1886.0	log Δ	Light
	h m s	° ′		
Nov. 17	20 7 26	−22 52.1	9.9231	2.7
19	16 56	22 17.9	9174	2.8
21	26 35	21 40.8	9118	2.9
23	36 22	21 0.6	9063	3.0
25	46 19	20 17.3	9009	3.1
27	56 23	19 30.8	8957	3.1
29	21 6 34	18 41.2	8907	3.2
Dec. 1	16 52	17 48.4	8860	3.2
3	27 16	16 52,4	8816	3.3
5	37 46	15 53.4	8776	3.3
7	48 21	14 51.3	8740	3.3
9	59 0	13 46.4	8709	3.3
11	22 9 42	12 38.8	8682	3.3
13	20 26	11 28.8	8661	3.3
15	31 13	−10 16.5	8646	3.2

New York City, 1886 *Nov.* 13.

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I have obtained the following observations of the comet. They may be somewhat rough, but any observation must be so unless the nucleus is well marked. I have taken approximate account of differential refraction.

1886	Greenw. M.T.	$\Delta\alpha$	$\Delta\delta$	1886.0 α	1886.0 δ
Nov. 15	11 42.0	+3 16.2	—22 12	19 57 53.6	—23 25 10
18	11 32.7	+0 27.5	—28 21	20 11 47.0	—22 38 0
19	11 37.3	+5 11.0	—11 2	20 16 30.5	—22 20 41

Units: Greenw. M.T. in h m; $\Delta\alpha$ in m s; $\Delta\delta$ in ′ ″; α in h m s; δ in ° ′ ″.

The comparison-star on November 15 was Lac. 8308; and on the other two dates F. 3 *Capricorni*. The places for 1886.0 taken from the Cordoba Catalogues, are

$19^h\ 54^m\ 37^s.40 \quad -23^\circ\ 2'\ 58''.5$

$20\ 11\ 19.53 \quad -22\ 9\ 39.3$

1886 *November* 20.

G. M. S.

NEW ASTEROIDS.

An asteroid was announced, November 1, as discovered by Dr. C. H. F. Peters, at Clinton, N.Y., in the position

(261) Oct. 31.790 Gr.M.T. $\alpha = 1^h\ 40^m$ $\delta = +\ 4^\circ\ 29'\ 13''$

Daily Motion —56^s in α, and $4'$ southward; 11^M.

Mr. Ritchie of the *Science Observer* has also courteously transmitted the cable-telegrams received by the S. O. code from Dr. Krueger, announcing the discovery of two more on the night of November 3 by Dr. Palisa at Vienna.

(262) Nov. 3.4822 Gr.M.T. $\alpha = 2^h\ 18^m\ 51^s.7$ $\delta = +\ 14^\circ\ 2'\ 17''$

Motion slow northward; 12^M.

(263) Nov. 3.4935 Gr.M.T. $\alpha = 2^h\ 17^m\ 58^s.3$ $\delta = +\ 13^\circ\ 46'\ 35''$

Daily Motion —48^s in α, and $3'$ southward; 12^M.

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ANALYTICAL DETERMINATION OF THE INEQUALITIES IN THE MOON'S MOTION ARISING FROM THE OBLATENESS OF THE EARTH.

By JOHN N. STOCKWELL.

PART II.

5 We shall first determine these inequalities by the method which is given in the author's *Theory of the Moon's Motion*. In this investigation we shall neglect the eccentricities of the orbits of the sun and moon, and also the square and higher powers of the inclination of the moon's orbit to the ecliptic. Then, if μ denotes the sum of the masses of the moon and earth, a and nt being the mean distance, and mean longitude, of the moon, we shall have the following equations for determining the perturbations of the polar coördinates r, v, and θ of the moon, to the required degree of accuracy.

$$\left.\begin{aligned} \frac{d\delta r}{dt} = {} & \frac{\cos nt}{\sqrt{a\mu}}\int\left\{-a^2\cos nt\left(\frac{dR}{dr}\right)+2a\sin nt\left(\frac{dR}{dv}\right)+a\gamma\left\{\sin(2nt-\Omega)+\sin\Omega\right\}\left(\frac{dR}{d\theta}\right)\right\}ndt \\ & -\frac{\sin nt}{\sqrt{a\mu}}\int\left\{a^2\sin nt\left(\frac{dR}{dr}\right)+2a\cos nt\left(\frac{dR}{dv}\right)+a\gamma\left\{\cos(2nt-\Omega)+\cos\Omega\right\}\left(\frac{dR}{d\theta}\right)\right\}ndt \end{aligned}\right\} \tag{1}$$

$$\frac{d\delta v}{dt} = -\frac{1}{a^2}\int\left(\frac{dR}{dv}\right)dt - 2\frac{n}{a}\delta r + 2n\gamma\sin(nt-\Omega)\,\delta\theta \tag{2}$$

$$\frac{d\delta\theta}{dt} = -\frac{\sin nt}{a^2}\int\sin nt\left(\frac{dR}{d\theta}\right)dt - \frac{\cos nt}{a^2}\int\cos nt\left(\frac{dR}{d\theta}\right)dt \tag{3}$$

$$\frac{d\Omega}{dt} = -\frac{an}{\mu}\,\frac{\sin nt}{\gamma}\sin(nt-\Omega)\left(\frac{dR}{d\theta}\right) \tag{4}$$

$$\frac{d\gamma}{dt} = -\frac{an}{\mu}\cos(nt-\Omega)\left(\frac{dR}{d\theta}\right) \tag{5}$$

in which R denotes the disturbing function, and γ and Ω denote the tangent of the inclination of the moon's orbit to the ecliptic, and the longitude of the ascending node, respectively.

The function R is composed of two kinds of terms; namely, those arising from the earth's oblateness, and those depending on the sun's attraction. We shall denote these terms by R_0 and R_1 respectively; so that we shall have

(6) $$R = R_0 + R_1.$$

If we also denote the corresponding perturbations of the coördinates arising from R_0 and R_1, by $\delta_0 r$, $\delta_0 v$, $\delta_0\theta$ and $\delta_1 r$, $\delta_1 v$, $\delta_1\theta$, we shall have

(7) $\delta r = \delta_0 r + \delta_1 r, \qquad \delta v = \delta_0 v + \delta_1 v, \qquad \delta\theta = \delta_0\theta + \delta_1\theta.$

The value of R must first be computed by means of the elliptical values of the coördinates; and this value of R will be correct to terms of the order of the first power of the disturbing force. We may then find the increment of R arising from the disturbing forces by means of the equation.

$$\delta R = \left(\frac{dR}{dr}\right)\delta r + \left(\frac{dR}{dv}\right)\delta v + \left(\frac{dR}{d\theta}\right)\delta\theta; \tag{8}$$

since R is a function of the coördinates r, v, and θ.

We shall neglect the terms arising from the squares and higher powers of the disturbing forces, but shall retain those depending on their product. If we now substitute the values of R, δr, δv, $\delta\theta$ given by equations (6, 7) in equation (8) we shall get for the required terms,

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$$\delta R = \left(\frac{dR_0}{dr}\right)\delta_1 r + \left(\frac{dR_0}{dv}\right)\delta_1 v + \left(\frac{dR_0}{d\theta}\right)\delta_1\theta + \left(\frac{dR_1}{dr}\right)\delta_0 r + \left(\frac{dR_1}{dv}\right)\delta_0 v + \left(\frac{dR_1}{d\theta}\right)\delta_0\theta. \tag{9}$$

The part of the function R which depends on the oblateness of the earth is denoted by R_0, and we have

(10) $$R_0 = (\rho - \tfrac{1}{2}\phi)\frac{D^2}{r^3}\mu\{\sin^2\mu' - \tfrac{1}{3}\};$$

in which ρ denotes the ellipticity of the earth; ϕ, the ratio of the centrifugal force to the gravity at the equator; D, the mean radius of the earth; and μ', the moon's declination. If we denote the obliquity of the ecliptic to the equator by ε we shall have

$$\sin\mu' = \sin\varepsilon\cos\theta\sin v + \cos\varepsilon\sin\theta. \tag{11}$$

This gives

$$\sin^2\mu' = \sin^2\varepsilon\cos^2\theta\sin^2 v + 2\sin\varepsilon\cos\varepsilon\sin\theta\cos\theta\sin v + \cos^2\varepsilon\sin^2\theta; \tag{12}$$

and if we put for abridgement

$$m_0 = (\rho - \tfrac{1}{2}\phi)D^2, \tag{13}$$

we shall obtain

$$R_0 = \frac{m_0\mu}{r^3}\{-\tfrac{1}{3}(1 - \tfrac{3}{2}\sin^2\varepsilon) + (1 - \tfrac{3}{2}\sin^2\varepsilon)\sin^2\theta - \tfrac{1}{2}\sin^2\varepsilon\cos^2\theta\cos 2v + 2\sin\varepsilon\cos\varepsilon\sin\theta\cos\theta\sin v\}. \tag{14}$$

Moreover, as we propose to investigate only the principal terms arising from the earth's figure, we may neglect everything except the last term in equation (14); and if we put

$$m = m_0\sin\varepsilon\cos\varepsilon, \tag{14'}$$

we shall get

(15) $$R_0 = 2\frac{m\mu}{r^3}\sin\theta\cos\theta\sin v.$$

In a first approximation we may neglect the sun's action, so that we shall have

(16) $$R = R_0 = 2\frac{m\mu}{r^3}\sin\theta\cos\theta\sin v.$$

This value of R gives

$$\left.\begin{aligned}\left(\frac{dR}{dr}\right) &= -6\frac{m\mu}{r^4}\sin\theta\cos\theta\sin v\\ \left(\frac{dR}{dv}\right) &= 2\frac{m\mu}{r^3}\sin\theta\cos\theta\cos v\\ \left(\frac{dR}{d\theta}\right) &= 2\frac{m\mu}{r^3}\{\cos^2\theta - \sin^2\theta\}\sin v.\end{aligned}\right\} \tag{17}$$

Since we neglect γ^2 and also suppose the orbits to be circular, we shall have

$$v = nt,\quad r = a,\quad \theta = \sin\theta = \tan\theta = \gamma\sin(nt - \Omega),\quad \cos\theta = 1; \tag{18}$$

and equations (17) become

$$\left.\begin{aligned}\left(\frac{dR}{dr}\right) &= 3\frac{m\mu}{a^4}\gamma\{\cos(2nt - \Omega) - \cos\Omega\}\\ \left(\frac{dR}{dv}\right) &= \frac{m\mu}{a^3}\gamma\{\sin(2nt - \Omega) - \sin\Omega\}\\ \left(\frac{dR}{d\theta}\right) &= 2\frac{m\mu}{a^3}\sin nt.\end{aligned}\right\} \tag{19}$$

6. If we substitute the value of $\left(\frac{dR}{d\theta}\right)$ in equation (3) and put $\frac{\mu}{a^3} = n^2$, we get the perturbation in latitude as follows:

$$\left.\begin{aligned}\frac{d\delta\theta}{dt} &= -\frac{mn^2}{a^2}\sin nt\int 2\sin^2 nt\,dt - \frac{mn^2}{a^2}\cos nt\int 2\sin nt\cos nt\,dt\\ &= -\frac{mn^2}{a^2}t\sin nt + \tfrac{1}{2}\frac{mn}{a^2}\cos nt.\end{aligned}\right\} \tag{20}$$

This gives by integration

$$\delta\theta = \tfrac{1}{2}\frac{m}{a^2}\sin nt - \frac{m}{a^2}\sin nt + \frac{m}{a^2}nt\cos nt = -\tfrac{1}{2}\frac{m}{a^2}\sin nt + \frac{m}{a^2}nt\cos nt. \tag{21}$$

7. We may obtain the same result by means of the variation of the elements. For equations (4) and (5) become

(22) $$\left\{\begin{aligned}\frac{d\Omega}{dt} &= \frac{mn}{a^2\gamma}\{\cos(2nt - \Omega) - \cos\Omega\}\\ \frac{d\gamma}{dt} &= -\frac{mn}{a^2}\{\sin(2nt - \Omega) + \sin\Omega\}.\end{aligned}\right.$$

To integrate these equations we may suppose the elements to be constant, and then make the elements variable in the integrals; or we may integrate them supposing the elements to be variable.

If we first suppose the elements to be constant, and put $\delta\Omega$ and $\delta\gamma$ for the integrals, we shall get

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$$(23)\quad \begin{cases} \gamma\delta\Omega = \frac{1}{2}\frac{m}{a^2}\sin(2nt-\Omega) - \frac{mnt}{a^2}\cos\Omega, \\ \delta\gamma = \frac{1}{2}\frac{m}{a^2}\cos(2nt-\Omega) - \frac{mnt}{a^2}\sin\Omega. \end{cases}$$

Now since θ is a function of γ and Ω, its variation will be given by the equation

$$(24)\qquad \delta\theta = \left(\frac{d\theta}{d\gamma}\right)\delta\gamma + \left(\frac{d\theta}{d\Omega}\right)\delta\Omega.$$

But we have

$$(24')\qquad \theta = \gamma\sin(nt-\Omega);$$

therefore equation (24) becomes

$$(25)\qquad \delta\theta = \sin(nt-\Omega)\,\delta\gamma - \cos(nt-\Omega)\,\gamma\delta\Omega$$

$$= -\frac{1}{2}\frac{m}{a^2}\sin nt + \frac{mnt}{a^2}\cos nt \qquad (26)$$

which is the same as (21), before found.

8. We will now integrate equations (22) on the supposition that the elements γ and Ω are variable by reason of the disturbing forces. We may suppose that γ is constant, since it is subject to periodic inequalities only; but Ω being subject to a secular variation, we shall suppose that

$$\Omega = \Omega_0 + \alpha t, \qquad (26')$$

in which α is a very small constant coefficient. The last terms of (22) being the only ones which increase by integration, we may suppose that Ω is constant in the other terms. Then we shall have

$$\left.\begin{aligned} \gamma d\delta\Omega &= \frac{m}{a^2}ndt\,\{\cos(2nt-\Omega) - \cos(\Omega_0+\alpha t)\} \\ d\delta\gamma &= -\frac{m}{a^2}ndt\,\{\sin(2nt-\Omega) + \sin(\Omega_0+\alpha t)\} \end{aligned}\right\} \qquad (27)$$

and these give by integration

$$\left.\begin{aligned} \gamma\delta\Omega &= \frac{1}{2}\frac{m}{a^2}\sin(2nt-\Omega) - \frac{mn}{a^2\alpha}\{\sin\Omega - \sin\Omega_0\} \\ \delta\gamma &= \frac{1}{2}\frac{m}{a^2}\cos(2nt-\Omega) + \frac{mn}{a^2\alpha}\{\cos\Omega - \cos\Omega_0\} \end{aligned}\right\} \qquad (28)$$

the constants $\sin\Omega_0$ and $\cos\Omega_0$ being added to the secular terms so that they may vanish at the epoch, when $t=0$.

Now we have

$$\frac{mn}{a^2\alpha}\{\sin\Omega - \sin\Omega_0\} = 2\frac{mn}{a^2\alpha}\sin\tfrac{1}{2}\alpha t\cos(\Omega - \tfrac{1}{2}\alpha t) = \frac{mnt}{a^2}\{\cos\Omega + \tfrac{1}{2}\alpha t\sin\Omega\} \qquad (29)$$

$$\frac{mn}{a^2\alpha}\{\cos\Omega - \cos\Omega_0\} = 2\frac{mn}{a^2\alpha}\sin\tfrac{1}{2}\alpha t\sin(\Omega - \tfrac{1}{2}\alpha t) = -\frac{mnt}{a^2}\{\sin\Omega - \tfrac{1}{2}\alpha t\cos\Omega\}. \qquad (30)$$

If we neglect the very small quantities $m\alpha$, the last terms of these equations will disappear, and equations (28) will become

$$(31)\quad \left.\begin{aligned} \gamma\delta\Omega &= \frac{1}{2}\frac{m}{a^2}\sin(2nt-\Omega) - \frac{mnt}{a^2}\cos\Omega \\ \delta\gamma &= \frac{1}{2}\frac{m}{a^2}\cos(2nt-\Omega) - \frac{mnt}{a^2}\sin\Omega \end{aligned}\right\}$$

the same as equations (23), which were found by the other method of integration. We have thus determined $\delta\theta$ by two different methods and found a perfect agreement between them.

9. In order to find the perturbations of the radius vector we must substitute the values of the functions given by equations (19) in equation (1) and we shall find, remembering always that $\sqrt{\frac{\mu}{a}} = an$,

$$\left.\begin{aligned} d\delta r = a\frac{m}{a^2}n\gamma dt\cos nt\int\{&-\tfrac{1}{2}\cos(3nt-\Omega) + \tfrac{3}{2}\cos(nt+\Omega) + 2\cos(nt-\Omega)\}ndt \\ -a\frac{m}{a^2}n\gamma dt\sin nt\int\{&\ \ \tfrac{1}{2}\sin(3nt-\Omega) - \tfrac{3}{2}\sin(nt+\Omega) - \sin(nt-\Omega)\}ndt. \end{aligned}\right\} \qquad (32)$$

Since the terms depending on the angles $nt \pm \Omega$ increase by integration, we must suppose Ω to be variable in these terms. Equation (32) will then become, after performing the integrations,

$$\left.\begin{aligned} d\delta r = a\frac{m}{a^2}n\gamma dt\cos nt\,\{&-\tfrac{1}{6}\sin(3nt-\Omega) + \tfrac{3}{2}\frac{n}{n+\alpha}\sin(nt+\Omega) + 2\frac{n}{n-\alpha}\sin(nt-\Omega)\} \\ -a\frac{m}{a^2}n\gamma dt\sin nt\,\{&-\tfrac{1}{6}\cos(3nt-\Omega) + \tfrac{3}{2}\frac{n}{n+\alpha}\cos(nt+\Omega) + \frac{n}{n-\alpha}\cos(nt-\Omega)\}. \end{aligned}\right\} \qquad (33)$$

This equation is easily reduced to the following

$$d\delta r = a\frac{m}{a^2}n\gamma dt\,\{-\tfrac{4}{3}\sin(2nt-\Omega) - 3\frac{n\alpha}{n^2-\alpha^2}\sin\Omega\} \qquad (34)$$

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which gives by integration

$$\delta r = a\frac{m}{a^2}\left\{\tfrac{1}{3}\left(1-\tfrac{3}{2}\sin^2\epsilon\right)+\tfrac{1}{3}\gamma\cos(2nt-\Omega)+3\gamma\frac{n^2}{n^2-\alpha^2}\cos\Omega\right\}. \tag{35}$$

The quantity $\frac{1}{3}(1-\frac{3}{2}\sin^2\epsilon)$ being added to complete the integral.

10. We must now find δv. If we multiply the second of equations (19) by dt and integrate, we find, after putting $\frac{\mu}{a^3}=n^2$,

$$\int\left(\frac{dR}{dv}\right)dt = mn^2\gamma\left\{-\frac{1}{2n}\cos(2nt-\Omega)-t\sin\Omega\right\}. \tag{36}$$

Multiply this by $-\frac{1}{a^2}$ and we get

$$\textit{1st term of}\qquad d\delta v=\frac{m}{a^2}n\gamma dt\left\{\tfrac{1}{2}\cos(2nt-\Omega)+nt\sin\Omega\right\}. \tag{37}$$

If we now multiply equation (35) by $-2\frac{n}{a}$, neglecting the constant term, we get

$$\textit{2nd term of}\qquad d\delta v=\frac{m}{a^2}\gamma\, ndt\left\{-\tfrac{2}{3}\cos(2nt-\Omega)-6\cos\Omega\right\}. \tag{38}$$

Lastly, if we multiply equation (21) by $2n\gamma\sin(nt-\Omega)$ we get

$$\textit{3d term of}\qquad d\delta v=\frac{m}{a^2}\gamma ndt\left\{\tfrac{1}{2}\cos(2nt-\Omega)-\tfrac{1}{2}\cos\Omega+nt\sin(2nt-\Omega)-nt\sin\Omega\right\}. \tag{39}$$

The sum of these last three equations gives the value of $d\delta v$; therefore

$$d\delta v=\frac{m}{a^2}\gamma ndt\left\{\tfrac{1}{3}\cos(2nt-\Omega)-\tfrac{13}{2}\cos\Omega+nt\sin(2nt-\Omega)\right\}; \tag{40}$$

and this gives by integration

$$\delta v=\frac{m}{a^2}\gamma\left\{\tfrac{5}{12}\sin(2nt-\Omega)-\tfrac{13}{2}\frac{n}{a}(\sin\Omega-\sin\Omega_0)-\tfrac{1}{2}nt\cos(2nt-\Omega)\right\}. \tag{41}$$

11. We shall now compute the value of δv by the method of the variation of the elements. For this purpose we shall take one of the fundamental equations of motion given by LAPLACE, book II, § 15, or [517] of BOWDITCH's translation of the *Mécanique Céleste*, as follows:

$$(42)\qquad \frac{ddr}{dt^2}-\frac{rdv^2}{dt^2}\cos^2\theta-\frac{rd\theta^2}{dt^2}=\left(\frac{dQ}{dr}\right)=-\frac{\mu}{r^2}-\left(\frac{dR}{dr}\right).$$

This gives, to the required degree of accuracy,

$$(43)\qquad \frac{dv}{dt}=\frac{\sqrt{\mu}}{r^{\frac{3}{2}}}\left\{1+\tfrac{1}{2}\frac{r^2}{\mu}\left(\frac{dR}{dr}\right)+\tfrac{1}{2}\frac{r^2}{\mu}\frac{ddr}{dt^2}\right\}.$$

Now we have $r=r_1+\delta r$, r_1 being the elliptical value of the radius vector; and since we neglect the eccentricity, we have

$$(43')\qquad r_1=a,\qquad ddr=dd\delta r;$$

therefore

$$\frac{dv}{dt}=\frac{\sqrt{\mu}}{a^{\frac{3}{2}}}\left\{1-\tfrac{3}{2}\frac{\delta r}{a}+\tfrac{1}{2}\frac{a^2}{\mu}\left(\frac{dR}{dr}\right)+\tfrac{1}{2}\frac{a^2}{\mu}\frac{dd\delta r}{dt^2}\right\}. \tag{44}$$

The first term of the second member of this equation is equal to n; therefore

$$\delta n=-\tfrac{3}{2}n\frac{\delta r}{a}+\tfrac{1}{2}n\frac{a^2}{\mu}\left(\frac{dR}{dr}\right)+\tfrac{1}{2}n\frac{a^2}{\mu}\frac{dd\delta r}{dt^2}. \tag{45}$$

The elliptical value of the longitude gives

$$\frac{dv}{dt}=n-\tfrac{1}{2}n\gamma^2\cos 2(nt-\Omega) \tag{46}$$

the last term being the reduction to the ecliptic.

The variation of this in terms of the variations of n, γ and Ω is

$$\frac{d\delta v}{dt}=\delta n-n\gamma\cos 2(nt-\Omega)-n\gamma\sin 2(nt-\Omega)\,\gamma\delta\Omega. \tag{46'}$$

Now we have from what precedes,

$$-\tfrac{3}{2}\frac{\delta r}{a}=\frac{m}{a}\gamma\left\{-\tfrac{1}{2}(\cos 2nt-\Omega)-\tfrac{9}{2}\cos\Omega\right\} \tag{47}$$

$$\tfrac{1}{2}\frac{a^2}{\mu}\left(\frac{dR}{dr}\right)=\frac{m}{a^2}\gamma\left\{\tfrac{3}{2}\cos(2nt-\Omega)-\tfrac{3}{2}\cos\Omega\right\} \tag{48}$$

$$\tfrac{1}{2}\frac{a^2}{\mu}\frac{dd\delta r}{dt^2}=\frac{m}{a^2}\gamma\left\{-\tfrac{2}{3}\cos(2nt-\Omega)\right\}. \tag{49}$$

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The last equation is found by taking the second differential of (35) and omitting the last term, since it would be multiplied by the very small quantity a^2.

The sum of equations (47–49) gives

$$\delta n = n\frac{m}{a^2}\gamma\left\{\tfrac{1}{3}\cos(2nt-\Omega)-6\cos\Omega\right\}. \quad (50)$$

If we substitute the values of $\delta\gamma$ and $\gamma\delta\Omega$ given by equations (23) in (46′), we shall get the terms

$$n\gamma\left\{\cos 2(nt-\Omega)\,\delta\gamma+\sin 2(nt-\Omega)\,\gamma\delta\Omega\right\}=n\frac{m}{a^3}\gamma\left\{\tfrac{1}{2}\cos\Omega-nt\sin(2nt-\Omega)\right\}. \quad (51)$$

The substitution of (50) and (51) in (46′) gives

$$\frac{d\delta v}{dt}=n\frac{m}{a^2}\gamma\left\{\tfrac{1}{3}\cos(2nt-\Omega)-\tfrac{13}{2}\cos\Omega+nt\sin(2nt-\Omega)\right\} \quad (52)$$

which is identically the same as equation (40), found by the other method.

OBSERVATIONS OF THE COMET 1886 *e* (*FINLAY*)

MADE AT THE DUDLEY OBSERVATORY, ALBANY.

(Communicated by the Director, Prof. Lewis Boss.)

1886 Albany M.T.	*	No. Comps.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
Sept. 29 7 29 18	1	20	—0 15.37	+6 7.6	17 9 46.63	—26 13 56.2	9.521	0.872
Oct. 16 8 1 51	2	1	+9 43.87	+5 49.8	17 59 2.94	26 39 7.0	9.604	0.843
22 7 11 38	3	10	+1 54.18	+1 2.0	18 19 29.54	26 31 54.4	9.531	0.870
23 7 14 54	4	5	+5 59.74	+0 37.9	18 23 5.47	26 29 31.2	9.538	0.868
Nov. 1 7 6 33	5	12 , 4	—3 27.76	+2 55.8	18 57 27.17	26 49 35.5	9.517	0.872
2 6 54 4.6	6	21 , 7	—0 40.69	+2 54.0	19 1 27.46	25 42 57.8	9.495	0.877
5 6 40 10.2	7	9 , 3	+2 43.91	—3 34.4	19 13 49.51	25 19 52.1	9.458	0.882
16 6 28 11	8	6 , 6	—0 10.05	+1 54.7	20 2 25.71	23 10 1.0	9.400	0.894
" 7 16 14	9	3 , 1	—4 55.17	+3 41.6	20 2 35.32	23 9 27.8	9.519	0.864
18 6 21 45	10	3 , 1	—4 12.55	+4 15.5	20 11 44.50	22 37 57.8	9.367	0.895
19 5 59 12	11	18 , 6	—1 18.39	+3 29.1	20 16 23.43	22 21 15.5	9.291	0.890
" 6 22 52	12	12 , 4	—4 57.92	+2 38.9	20 16 28.47	22 20 56.2	9.377	0.884
21 6 20 31	13	12 , 4	—5 45.49	+4 21.1	20 25 59.60	21 44 43.0	9.362	0.883
" 7 2 39	14	15 , 5	—4 52.40	—0 34.0	20 26 7.78	—21 44 15.0	9.478	0.868

Adopted Mean Places for 1886.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	17 10 0.23	+1.77	—26 20 4.8	+ 4.6	Oe. Argel. 16548
2	17 49 17.41	1.66	26 45 3.4	6.6	Stone 9766
3	18 17 33.66	1.70	26 33 4.1	7.7	Yarnall 7784
4	18 17 4.05	1.68	26 30 16.8	7.7	" 7779
5	19 0 53.22	1.71	25 52 40.8	9.5	½(Yarnall 8127+St. 10392)
6	19 2 6.45	1.70	25 40 13.4	9.6	Argentine Gen. Catal. 26207
7	19 11 3.91	1.69	25 16 27.6	9.9	Bonn VI., 5 obs.
8	20 2 34.05	1.71	23 12 7.4	11.7	Wash. Zones, corrected
9	20 7 28.73	1.76	23 13 21.2	11.8	" " "
10	20 15 55.29	1.76	22 42 25.3	12.0	Yarnall 8826
11	20 17 40.09	1.73	22 24 56.7	12.1	3 Wash. Zones, with Bonn VI
12	20 21 24.64	1.75	22 23 47.2	12.1	5 " " " " "
13	20 31 43.34	1.75	21 49 16.5	12.4	Yarnall 8951
14	20 30 58.45	+1.73	—21 43 53.3	+12.3	Wash. Zones (2)

Except on September 29, the filar micrometer was used in all the observations. The first four observations are by H. V. Egbert; the remaining eight by L. Boss.

Wherever, by comparison with star-places derived from Yarnall's Catalogue, an apparently well-founded correction to the Washington Zones could be derived, it has been applied. Such corrections have

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been used as follows: — Merid. Circle Zone, No. 53, $+3^s.6$, $+1''.8$; Mural Circle Zone, No. 186, $+2''.7$; Transit Zone, No. 179, $-0^s.30$; No. 192, $+2''.1$. In the case of stars 8 and 9, they were corrected so as to make the differences of the apparent places on November 16 conform to the differences measured with the filar micrometer on that night.

The observation of October 16 is not regarded by the observer as particularly strong, and this may well be, owing to the large hour-angle at which the comet was observed, and the foggy condition of the atmosphere.

There was a moderately thick fog on November 16, during the observations, followed by clouds. The sky suddenly clouded after the single comparison of November 18; but, possible errors of counting seconds or micrometer-revolutions excepted, the observation is a good one. The comet was bright, with strong nuclear condensation.

The comet was bright on November 19, until a bank of clouds suddenly rising hid it from view. Light of central condensation estimated as equal to that of a star of the magnitude 9.5. The coma appeared to be 2′ or 3′ in diameter.

The Catalogue of ARGELANDER's Southern Zones from 19^h to 24^h, and GOULD's Zone-observations at Cordoba, are not included in the library of this observatory.

A NEW SHORT-PERIOD VARIABLE IN *AQUILA*.

$19^h\ 22^m\ 38^s$; $-7°\ 17'.9$ (1875.0)

BY EDWIN F. SAWYER.

I beg to announce that I have discovered the star 50 (U. A.) *Aquilae*, to be a variable of short period. The magnitude of the star in the *Uranometria Argentina* is 7.0. My observations of 1882 September 15, and 1886 September 21, give the magnitude of the star as 6.7 and 6.8 respectively, being fairly accordant. On the evening of 1886 October 22, however, while examining the stars in its vicinity, I was struck with its unusual faintness, and it was marked for future examination. On the two following evenings the star still remained faint, but on the third evening (October 25) it was found very bright, and its variability established beyond doubt.

A preliminary reduction of my observations so far obtained indicates that the period is about one week. The range of fluctuation is between the magnitudes 6.4 and 7.3 The star appears colorless. The comparison-stars used and the preliminary light-scale adopted are given below; the positions being for the mean equinox of 1875.0.

The star is 6.7 mag. in Heis.

		α	δ	U.A.	Sawyer	Light-Scale
		h m s	° ′	M	M	
a =	100 (U.A.) *Aquilae*	19 52 59	—10 17.0	6.1	6.1	18.0
b =	92 " "	19 47 21	— 8 53.8	6.2	6.25	16.6
c =	80 " "	19 42 9	—11 10.7	6.4	6.4	15.0
d =	60 " "	19 28 45	— 7 43.9	6.7	6.65	11.0
e =	43 " "	19 16 20	— 7 38.2	6.7	6.7	9.7
f =	W.B 280 "	19 13 19.6	— 6 51.5		7.1	6.0
g =	W.B. 568 "	19 24 12.3	— 6 46.2		7.5	1.3

From the above light-scale the following light-values for the variable have been determined:—

	d	h	m	Light
1882, Sept.	15	10	15	8.7
1886, "	21	8	50	9.8
Oct.	19	7	0	11.0
	22	7	0	7.0
	23	6	45	5.0
	24	6	30	9.1
	25	7	0	13.9
Nov.	1	6	10	14.8 ::
1886, Nov.	2	6	0	10.0 :
	4	6	10	7.5
	5	6	0	5.3*
	7	6	0	9.3*
	8	6	0	13.6*
	9	5	45	12.0*
	14	5	45	8.2
	15	5	45	14.0 :

*Moonlight.

Cambridgeport, 1886 *Nov.* 15.

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ELEMENTS AND EPHEMERIS OF THE COMET 1886 *f* (*BARNARD, OCT. 4.*)

BY S. C. CHANDLER, JR.

From an observation on the 25th, kindly furnished me to-day by Mr. WENDELL, of the Harvard College Observatory, combined with the position at Kiel on October 29, and the mean of those at Albany, Copenhagen, Cambridge and Nashville, on October 6, I have computed the following orbit.

POSITIONS CORRECTED FOR PARALLAX AND ABERRATION.

Greenwich M.T.	α 1886.0	δ 1886.0
	h m s	° ′ ″
1886 Oct. 6.847268	10 39 57.90	+ 1 13 12.0
29.689826	11 39 19.62	+ 5 49 23.5
Nov. 25.953206	14 18 54.87	+16 21 48.8

ELEMENTS.

$$T = 1886 \text{ Dec. } 16.49477 \text{ Green. M.T.}$$

$$\left.\begin{aligned} \omega &= 86^\circ\, 21'\, 16''.8 \\ \Omega &= 137\;\; 22\;\; 41\;.2 \\ i &= 101\;\; 39\;\; 19\;.1 \end{aligned}\right\} 1886.0$$

$$\log q = 9.8216054$$

$$\text{C} - \text{O} \left\{ \begin{aligned} \Delta\lambda \cos\beta &= +2''.5 \\ \Delta\beta &= -2\;.6 \end{aligned} \right.$$

EQUATOR-CONSTANTS.

$$x = r\,[9.8741610] \sin\,[v + \;\;6^\circ\, 53'\, 11''.2]$$
$$y = r\,[9.8266688] \sin\,[v + 198\;\; 32\;\; 54\;.4]$$
$$z = r\,[9.9977513] \sin\,[v + 102\;\;\; 4\;\; 24\;.6]$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1886	App. α	App. δ	log r	log Δ	L
	h m s	° ′			
Dec. 3.5	15 37 59	+18 0.4	9.8555	9.9852	23.1
5.5	16 0 28	17 56.8			
7.5	16 22 53	17 39.3	9.8386	9.9871	24.7
9.5	16 44 51	17 7.2			
11.5	17 6 7	16 22.5	9.8270	0.0005	24.5
13.5	17 26 18	15 26.2			
15.5	17 45 19	14 21.0	9.8218	0.0234	22.6
17.5	18 2 57	13 9.3			
19.5	18 19 17	11 53.1	9.8236	0.0523	19.6
21.5	18 34 16	10 34.5			
23.5	18 48 2	9 14.9	9.8321	0.0841	16.3
25.5	19 0 37	7 55.7			
27.5	19 12 10	6 37.6	9.8465	0.1165	13.1
29.5	19 22 45	5 21.9			
31.5	19 32 32	+ 4 8.1	9.8656	0.1479	10.4

Cambridge, 1886 *November* 27.

ON THE ORBIT OF THE PERIODIC COMET 1886 *e* (*FINLAY*)

BY PROF. LEWIS BOSS.

The elements of the comet discovered by FINLAY, which are included in this article, were derived from four normal places constructed by the aid of the elements, which are printed in No. 146 of the *Astronomical Journal*. The epoch of the first normal place is September 30.5 (G.M.T.) and the place is founded on observations made at Rome (2), Nice (2), Lyons (2), Vienna (2), Washington (2), Nashville and Albany. M. PERROTIN's observation of September 29, as printed in the *Comptes Rendus* (No. 14), was, however, first corrected for proper-motion of the star used, for which NEWCOMB's position and proper-motion, as in his Zodiacal Catalogue, were adopted. The second normal place, at date October 23.0, comprised four filar-micrometer observations: those at Washington, October 22 and 23, and at Albany on the same dates. The third was made up of three Albany filar-micrometer observations—November 1, 2 and 5—combined by weights to make the mean date, November 3.0. The final place consisted of two Albany filar-micrometer observations, November 19.43. As in my elements, printed in a previous number of this Journal, the computation was so conducted as to make no use of the middle latitudes. The following elements result:

$$T = 1886 \text{ November } 22.39510 \text{ Gr.M.T.}$$

$$\left.\begin{aligned} \pi &= \;\;7^\circ\, 51'\;\; 6''.9 \\ \omega &= 315\;\; 16\;\; 52\;.3 \\ \Omega &= \;\;52\;\; 34\;\; 14\;.6 \\ i &= \;\;\;3\;\;\; 1\;\; 26\;.8 \end{aligned}\right\} \text{Ecliptic and Equinox 1886.0}$$

$$\log e = 9.853910$$
$$\log q = 9.997917$$
$$\log a = 0.542080$$

Approximate Period $6^y.503$

EQUATIONS OF THE HELIOCENTRIC COORDINATES:

$$x = r\,[9.999619] \sin\,(v + 97^\circ\, 48'\, 48''.1)$$
$$y = r\,[9.956318] \sin\,(v + \;\;8\;\; 56\;\; 51\;.0)$$
$$z = r\,[9.632381] \sin\,(v + \;\;2\;\; 44\;\; 49\;.5)$$

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The direct comparison with the place of October 23.0 gave (C—O): $\Delta\lambda = +0''.6$; $\Delta\beta$ —4″.8.

As the computation was independent of this latitude, the comparative smallness of $\Delta\beta$ may be regarded as testimony favorable to the accuracy of the above elements, especially since this place is nearly midway between the extreme observations. In order, however, to test the elements, in some degree, the subjoined results of comparisons of them with the observations cited are given. The signs are those resulting from subtraction of the observed places from the computed.

		C—O $\Delta\alpha$	C—O $\Delta\delta$
		s	″
Sept. 29	Rome	—0.1	— 5
	Nice	—0 3	+ 1
	Lyons	+0.3	— 3
	Albany	+0.8	— 0
	Nashville	—0.5	+ 9
30	Vienna	—0.8	— 3
	Lyons	—0.5	— 1
	Washington	+0.2	+ 3
Oct. 1	Vienna	+0.4	+15
	Rome	0.0	+12
	Nice	+0.3	— 4
	Washington	+0.1	—11
22	Albany	0.0	— 3
	Washington	—0.1	— 5
23	Albany	—0.1	— 1
	Washington	—0.3	—11
Nov. 1	Albany	—0.5	— 3
2	Albany	—0.1	— 2
5	Albany	—0.8	— 2
19	Albany (1)	—0.2	— 2
	" (2)	—0.5	— 4
21	Albany (1)	+0.6	+ 3
	" (2)	+0.7	+ 9*

*The star-place is from Washington Zones alone.

Albany, 1886 *December* 3.

Notwithstanding this apparently favorable showing, the determination of the semi-axis and consequent periodic time is liable to important corrections. Yet I can hardly believe that the period is less than six years; for a value exceeding that amount would have been given by any one of the final three approximations which I made for the radii vectores and the included arc. This fact renders it, in my opinion, extremely probable that the comet has made only seven revolutions since its appearance in 1884; and that the effect of the great perturbations which the elements have probably experienced has been to lengthen rather than to diminish the period found by BRÜNNOW.

I desire to call the attention of observers to the increasingly favorable situation of the comet for observation in this hemisphere, and to express the hope that no opportunity for observing it be neglected. Though the comet will diminish slowly in brightness after the middle of December, it ought to be well seen for at least two months to come.

The following ephemeris for Greenwich midnight has been computed for the convenience of observers.

EPHEMERIS FOR GREENWICH 12h.

Date	☄ App. α			☄ App. δ			log Δ
	h	m	s	°	′	″	
1886 Dec. 3	21	25	46.9	—17	4	10	9.9226
5		36	0.6	16	7	25	9.9207
7		46	17.4	15	8	8	9.9172
9		56	36.8	14	6	13	9.9151
11	22	6	57.7	13	1	57	9.9134
13		17	19.6	11	55	28	9.9123
15		27	41.7	10	47	5	9.9116
17		38	3.2	9	36	57	9.9117
19		48	23.5	8	25	24	9.9121
21		58	41.7	7	12	40	9.9132
23	23	8	57.3	5	59	6	9.9149
25		19	9.4	4	44	59	9.9172
27		29	17.4	3	30	38	9.9201
29		39	20.5	2	16	22	9.9236
31		49	18.4	1	2	28	9.9277

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THE

ASTRONOMICAL JOURNAL.

No. 148.

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ANALYTICAL DETERMINATION OF THE INEQUALITIES IN THE MOON'S MOTION ARISING FROM THE OBLATENESS OF THE EARTH.

BY JOHN N. STOCKWELL.

PART III.

12 We have thus determined the inequalities arising from the earth's oblateness by two different methods of calculation, and have obtained the same results, and we shall now apply LAPLACE's formulas to the solution of the same problem.

For this purpose we shall take the formulas [926] and [923] *Méc. Cél.* which are easily reduced to the following

$$(53)\qquad \frac{ddr\delta r}{dt^2}+\frac{\mu r\delta r}{r^3}+2\int \mathrm{d}R+r\left(\frac{dR}{dr}\right)=0$$

$$(54)\qquad d\delta v=\frac{2d\,(rd\delta r)+dt^2\,3\int \mathrm{d}R+2r\left(\frac{dR}{dr}\right)}{r^2dv}$$

in which the symbol d refers only to the coördinates of the moon. Also [932] and [5347f] *Méc. Cél.* become (55)

$$\mu\delta s=a\cos v\int ndt\sin vr\left(\frac{dR}{dz}\right)-a\sin v\int ndt\cos vr\left(\frac{dR}{dz}\right)$$

$$(56)\qquad \frac{dds}{dv^2}+s+\frac{r^2}{a}\left(\frac{dR}{ds}\right)=0.$$

since $h^2u^2=\frac{a}{r^2}$.

Now we have

$$(57)\qquad \mathrm{d}R=\left(\frac{dR}{dr}\right)dr_0+\left(\frac{dR}{dv}\right)dv_0+\left(\frac{dR}{ds}\right)ds_0$$

in which s denotes the tangent of the latitude, and r_0, v_0, s_0 denote the elliptical values of the coördinates.

Since we neglect γ^2 and also the eccentricity of the orbit, we may put $v=nt$ and $s=\theta$, in the expressions for the forces, which will then become

$$(58)\qquad \left(\frac{dR}{dr}\right)=3\,\frac{m\mu}{a^4}\,\gamma\,\{\cos\,(2v-\Omega)-\cos\Omega\}$$

$$(59)\qquad \left(\frac{dR}{dv}\right)=\frac{m\mu}{a^3}\,\gamma\,\{\sin\,(2v-\Omega)-\sin\Omega\}$$

$$(60)\qquad \left(\frac{dR}{d\theta}\right)=\left(\frac{dR}{ds}\right)=2\,\frac{m\mu}{a^3}\sin v.$$

We shall also have with sufficient precision for computing the forces (60′)

$$r=a,\qquad dr=0,\qquad v=v_0,\qquad s=s_0=\theta=\gamma\sin\,(v-\Omega).$$

Then we find

$$dv=dv_0,\qquad ds=ds_0=\gamma dv\cos\,(v-\Omega),\qquad (61)$$

$$\left.\begin{aligned}\left(\frac{dR}{dr}\right)dr&=0\\ \left(\frac{dR}{dv}\right)dv&=\frac{m}{a^2}\mu\gamma\,dv\,\{\sin\,(2v-\Omega)-\sin\Omega\}\\ \left(\frac{dR}{ds}\right)ds&=\frac{m}{a^2}\mu\gamma\,dv\,\{\sin\,(2v-\Omega)+\sin\Omega\}\end{aligned}\right\}\qquad (62)$$

Substituting in (57) we get

$$\mathrm{d}R=2\,\frac{m\mu}{a^3}\,\gamma\,dv\sin\,(2v-\Omega)\,;\qquad (63)$$

and this gives by integration

$$\int \mathrm{d}R=-\frac{m\mu}{a^3}\,\gamma\cos\,(2v-\Omega).\qquad (64)$$

If we substitute this, and the value of $\left(\frac{dR}{dr}\right)$ in equation (53) it will reduce to the following, since $r=a$ and $dv=ndt$,

$$\frac{dd\delta r}{dv^2}+\delta r+a\,\frac{m}{a^2}\gamma\,\{\cos\,(2v-\Omega)-3\cos\Omega\}=0\qquad (65)$$

and this gives by integration

$$\delta r=a\,\frac{m}{a^2}\gamma\,\{\tfrac{1}{3}\cos\,(2v-\Omega)+\frac{3}{1-a^2}\cos\Omega\}\qquad (66)$$

which is equivalent to the value found in (35), omitting the constant term.

Now we have

$$\left.\begin{aligned}3\int \mathrm{d}R&=\frac{m\mu}{a^3}\,\gamma\,\{-3\cos\,(2v-\Omega)\}\\ 2r\left(\frac{dR}{dr}\right)&=\frac{m\mu}{a^3}\,\gamma\,\{6\cos\,(2v-\Omega)-6\cos\Omega\}\end{aligned}\right\}\qquad (67)$$

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and equation (66) gives, by taking its second differential and omitting the last term, since it is multiplied by the very small quantity α^2,

$$2\,rdd\delta r = m\gamma\,\{-\tfrac{8}{3}\cos(2v-\Omega)\}\,dv^2 = \frac{m\mu}{a^3}\gamma\,\{-\tfrac{8}{3}\cos(2v-\Omega)\}\,dt^2. \tag{68}$$

Equation (54) therefore becomes, since $\mu = a^3n^2$,

$$(69)\quad \left\{\begin{aligned} d\delta v &= \frac{m}{a^2}\gamma\frac{n^2dt^2}{dv}\{\tfrac{1}{3}\cos(2v+\Omega)-6\cos\Omega\}\\ &= \frac{m}{a^2}\gamma\,dv\,\{\tfrac{1}{3}\cos(2v-\Omega)-6\cos\Omega\}\end{aligned}\right.$$

This value of $d\delta v$ corresponds to the plane of the orbit, and in order to reduce it to the plane of the ecliptic we must add the following term

$$\tfrac{1}{2}\left\{s^2-\frac{ds^2}{dv^2}\right\}dv$$

Méc. Cél. [5382]; and this requires the determination of the perturbation in latitude, or δs.

Now since $z = rs$ we shall have

$$(70)\quad \left(\frac{dR}{ds}\right)=\left(\frac{dR}{dz}\right)\frac{dz}{ds}=r\left(\frac{dR}{dz}\right)=2\,\frac{m\mu}{a^3}\sin v.$$

If we substitute this in equation (55) it becomes

$$\left.\begin{aligned}\delta s &= \frac{m}{a^2}\cos v\int 2dv\sin^2 v-\frac{m}{a^2}\sin v\int 2\sin v\cos v\,dv\\ &= -\tfrac{1}{2}\frac{m}{a^2}\sin v+\frac{m}{a^2}v\cos v\end{aligned}\right\}\tag{71}$$

which is equivalent to equation (21), and becomes identical with it by changing v into nt. The complete value of s is therefore given by the equation

$$s = \gamma\sin(v-\Omega)-\tfrac{1}{2}\frac{m}{a^2}\sin v+\frac{m}{a^2}v\cos v. \tag{72}$$

This gives

$$ds = \{\gamma\cos(v-\Omega)+\tfrac{1}{2}\frac{m}{a^2}\cos v-\frac{m}{a^2}v\sin v\}\,dv. \tag{73}$$

The squares of these equations contain the terms

$$\left.\begin{aligned} s^2 &= \tfrac{1}{2}\frac{m}{a^2}\gamma\,\{\cos(2v-\Omega)-\cos\Omega\}+\frac{m}{a^2}v\,\gamma\,\{\sin(2v-\Omega)-\sin\Omega\}\\ \frac{ds^2}{dv^2} &= \tfrac{1}{2}\frac{m}{a^2}\gamma\,\{\cos(2v-\Omega)+\cos\Omega\}-\frac{m}{a^2}v\,\gamma\,\{\sin(2v-\Omega)+\sin\Omega\}\end{aligned}\right\}\tag{74}$$

Therefore

$$\tfrac{1}{2}\left\{s^2-\frac{ds^2}{dv^2}\right\}=-\tfrac{1}{2}\frac{m}{a^2}\gamma\cos\Omega+\frac{m}{a^2}v\gamma\sin(2v-\Omega). \tag{75}$$

If we add this to equation (69), we get the complete value of $d\delta v$, as follows:

$$d\delta v = \frac{m}{a^2}\gamma\,\{\tfrac{1}{3}\cos(2v-\Omega)-\tfrac{13}{2}\cos\Omega+v\sin(2v-\Omega)\}\,dv, \tag{76}$$

which is the exact equivalent of equation (40).

We see from equations (62) that the terms which depend upon the longitude of the node in the expressions of the forces $\left(\frac{dR}{dv}\right)$ and $\left(\frac{dR}{ds}\right)$ cancel each other in the expression of dR. These terms, therefore, have no effect upon the radius-vector and longitude.

13 The most elegant method of deducing the inequalities in the moon's latitude arising from the oblateness of the earth is, perhaps, that developed by LaPlace in chapter VIII, book II, [1337]; and also in the appendix to the third volume [5790, 5791] of the *Mécanique Céleste*. He has there given the differential variations of the elements in terms of the partial differentials of the forces taken with respect to the elements themselves. We shall now apply that method, and shall then proceed to examine LaPlace's calculations of these inequalities, and shall point out what we conceive to be fundamental defects or errors in his investigations.

14 For this purpose we must first put the expression of the moon's latitude under a different form. Now we have

$$(77)\quad s=\gamma\sin(v-\Omega)=\gamma\cos\Omega\sin v-\gamma\sin\Omega\cos v$$

and if we put

$$p=\gamma\sin\Omega,\quad q=\gamma\cos\Omega \tag{78}$$

we shall have

$$s = q\sin v-p\cos v. \tag{79}$$

Now by substituting s for θ in equation (16) the value of R becomes

$$R = 2\,\frac{m\mu}{r^3}s\sin v \tag{80}$$

and if we substitute the value of s (79) we get

$$R = \frac{m\mu}{r^3}\{q-q\cos 2v-p\sin 2v\} \tag{81}$$

Equations [1337] *Méc. Cél.* become, by substituting the value of c and neglecting e^2,

$$\left.\begin{aligned} dq &= \frac{andt}{\mu}\left(\frac{dR}{dp}\right)=\frac{adv}{\mu}\left(\frac{dR}{dp}\right)\\ dp &= -\frac{andt}{\mu}\left(\frac{dR}{dq}\right)=-\frac{adv}{\mu}\left(\frac{dR}{dq}\right)\end{aligned}\right\}\tag{82}$$

Equation (81) gives

$$\left(\frac{dR}{dp}\right)=-\frac{m\mu}{r^3}\sin 2v,\quad \left(\frac{dR}{dq}\right)=\frac{m\mu}{r^3}\{1-\cos 2v\} \tag{83}$$

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Therefore we get

$$(84)\qquad \begin{cases} dq = -\dfrac{m}{a^2}\,dv\sin 2v \\ dp = \dfrac{m}{a^2}\,dv\,\{\cos 2v - 1\} \end{cases}$$

If we put δp and δq for the integrals of these equations we shall find by integration

$$(85)\qquad \delta p = \tfrac{1}{2}\frac{m}{a^2}\sin 2v - \frac{m}{a^2}v\,; \qquad \delta q = \tfrac{1}{2}\frac{m}{a^2}\cos 2v.$$

Adding these quantities to the elliptical values, we get for the complete values of p and q

$$(86)\qquad \begin{cases} p = \gamma\sin\Omega + \tfrac{1}{2}\dfrac{m}{a^2}\sin 2v - \dfrac{m}{a^2}v \\ q = \gamma\cos\Omega + \tfrac{1}{2}\dfrac{m}{a^2}\cos 2v \end{cases}$$

and if we substitute these values in (79) we get

$$(87)\qquad s = \gamma\sin(v-\Omega) - \tfrac{1}{2}\frac{m}{a^2}\sin v + \frac{mv}{a^2}\cos v$$

which agrees with each of the other methods.

15 We have thus given four different computations of the values of δv and $\delta\theta$ and have found that they all agree with each other. It now remains to examine the calculations of LAPLACE and other investigators.

In the preceding calculations we have supposed that the longitudes are reckoned from a fixed equinox, but LAPLACE has assumed them to be reckoned from the movable equinox. This is effected by multiplying v by a factor f, in which f differs from unity by the ratio of the motion of the equinox to the moon's mean motion. The numerical value of f is

$$(87')\qquad f = 1.00000289975\,;$$

and in all the numerical calculations f is put equal to unity.

LAPLACE has taken the sum of the masses of the earth and moon for the unity of mass, so that we shall now put $\mu = 1$; and has correctly given the differential equation of the latitude in [5347 m], BOWDITCH *Méc. Cél.*, as follows:

$$(88)\qquad \frac{dds}{dv^2} + s + \{2\frac{m}{a^2} + (g^2-1)H\}\sin fv = 0\,;$$

in which

$$(89)\qquad m = (a\rho - \tfrac{1}{2}a\phi)\,D^2\sin\lambda\cos\lambda$$

according to LAPLACE's notation, and the term $(g^2-1)H\sin fv$ arises from the earth's indirect action, or, in other words, it is the sun's action as modified by the earth's oblateness. It was calculated by assuming that the inequality arising from the earth's figure is equal to

$$(90)\qquad \delta s = H\sin fv$$

and is therefore of the order of the product of the disturbing functions due to the earth and sun.

The general integral of equation (88) being denoted by δs, is

$$\delta s = \frac{\dfrac{2m}{a^2} + (g^2-1)H}{f^2-1}\sin fv. \qquad (91)$$

If we put this equal to the assumed value of δs we get the equation

$$\frac{\dfrac{2m}{a^2} + (g^2-1)H}{f^2-1}\sin fv = H\sin fv. \qquad (92)$$

Now if we omit the factor $\sin fv$, and multiply by $f^2 - 1 = 0$, we get

$$2\frac{m}{a^2} + (g^2-1)H = 0, \text{ and } H = -\frac{2m}{a^2(g^2-1)} \qquad (93)$$

which is the value of H given by LAPLACE, *Méc. Cél.* [5350].

But if we substitute this value of H in equation (91) it becomes

$$\delta s = \frac{0}{0}\sin fv \qquad (94)$$

an equation which is satisfied by all values of δs; or, in other words, the value of δs is indeterminate. Moreover, if we substitute the same value of H in the differential equation (88) it becomes

$$\frac{dds}{dv^2} + s = 0 \qquad (95)$$

the integral of which is

$$s = \gamma\sin(v-\Omega) \qquad (96)$$

as in equation (60′) corresponding to the elliptical motion; therefore $\delta s = 0$. This is as it should be, because, if the earth's *direct action* on the moon is equal and contrary to its *indirect action*, there would be an equilibrium between the forces, and no perturbation should result.

Suppose now that we omit the term $(g^2-1)H$ in equation (88), we then have

$$\frac{dds}{dv^2} + s + 2\frac{m}{a^2}\sin fv = 0 \qquad (97)$$

arising from the earth's action alone. The general integral of this equation is

$$\delta s = \frac{2m}{a^2(f^2-1)}\sin fv = \frac{2m}{0}\sin fv \qquad (98)$$

which is infinite and positive, and indicates a *repelling* rather than *attractive* force arising from the protuberant matter at the earth's equator.

16 In order to explain these very curious results, we shall observe that they arise from the fact that *the general formula of integration fails in the case where $f = 1$*. LAPLACE has noticed this circumstance in *Méc. Cél.* [871″] and has conformed to this restriction in all parts of the *Mécanique Céleste* except in the "*Theory of the Moon.*"

Now the correct integral of equation (88) is

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$$\delta s = -\tfrac{1}{2}\frac{m}{a^2}\sin fv + \frac{m}{a^2}v\cos fv - \tfrac{1}{2}(g^2-1)H\sin fv + \tfrac{1}{2}(g^2-1)Hv\cos fv; \tag{99}$$

the first two terms of which arise from the earth's direct action, and are the same as before found in equation (71); and if we substitute $H = -\frac{1}{2}\frac{m}{a^2}$ in the last two terms of (99) we shall obtain the effect arising from the earth's indirect action, very nearly.

17 We shall now examine LAPLACE's calculation of the inequalities of the radius-vector and of the longitude; and for this purpose shall employ equations (53, 54). These equations contain dR, in which the symbol d refers only to the coördinates of the moon. It is therefore necessary to have expressions for these coördinates, since their differentials enter into the expression for dR according to equation (57).

Now if we suppose the moon to move in a pure elliptic orbit, equation (57) gives the value of dR correct to terms of the first power of the disturbing forces. We may suppose the latitude in a pure elliptic orbit to be given by the equation

$$s_0 = \gamma \sin(v_0 - \Omega_0) \tag{100}$$

in which γ and Ω_0 are constant and denote the tangent of the inclination of the moon's orbit to the ecliptic, and the longitude of its ascending node, respectively; while v_0 denotes the undisturbed longitude. Now, by reason of the sun's attraction, the nodes of the moon's orbit retrograde on the ecliptic, while the moon itself moves at a different distance from the earth, and with a different velocity than it otherwise would. The inclination of the orbit, however, remains constant. Then, if in the movable orbit we denote the longitude, latitude and node by v, s and Ω, we shall have

$$s = \gamma \sin(v - \Omega) \tag{101}$$

in which Ω is variable.

Now LAPLACE supposed that the theory of the moon's motion could be more advantageously treated by referring the coördinates to the disturbed, rather than to the undisturbed, orbit. He therefore made use of equation (101) and supposed that

$$\Omega = \Omega_0 - (g-1)v \tag{102}$$

in which $(g-1)v$ denotes the retrograde motion of the nodes, and equation (101) becomes

$$s = \gamma \sin(gv - \Omega_0). \tag{103}$$

18 *It is, however, a curious fact that the latitude of the moon in the disturbed orbit is the same as it would have been in the undisturbed orbit, in so far as the mean motion of the nodes affect that coördinate.* Although this fact has never before been noticed, it may easily be proved as follows:

The quantity g expressed analytically is given by the equation *Méc. Cél.* [5374]

$$g = 1 + \tfrac{3}{4}\bar{m}^2 \tag{104}$$

in which $\bar{m}^2$ denotes the disturbing function arising from the sun's action. Now the relation between the mean distances in the disturbed and undisturbed orbits is expressed by the equation *Méc. Cél.* [4968, 5091]

$$a_0 = a\{1 - \tfrac{1}{2}\bar{m}^2\} \tag{105}$$

in which a_0 denotes the undisturbed mean distance. We also have, *Méc. Cél.* [5092]

$$\frac{1}{n} = a^{\frac{3}{2}}\{1 + \tfrac{1}{4}\bar{m}^2\} \tag{106}$$

in which n denotes the mean motion in a unit of time. The mean motion at the distance a_0 when subject to the same disturbance would be expressed by the equation

$$\frac{1}{n_0} = a_0^{\frac{3}{2}}\{1 + \tfrac{1}{4}\bar{m}^2\}. \tag{107}$$

If we substitute the value of a_0, given by equation (105), in (107) we get

$$\frac{1}{n_0} = a^{\frac{3}{2}}\{1 + \tfrac{1}{4}\bar{m}^2\}\{1 - \tfrac{3}{4}\bar{m}^2\} = a^{\frac{3}{2}}\{1 - \tfrac{1}{2}\bar{m}^2\}. \tag{108}$$

Dividing equation (106) by (108) we get

$$n_0 = n\{1 + \tfrac{3}{4}\bar{m}^2\} \tag{109}$$

and since $v_0 = n_0 t$ and $v = nt$, we shall evidently have

$$v_0 = v\{1 + \tfrac{3}{4}\bar{m}^2\} = gv \tag{110}$$

and this substituted in (103) gives

$$s = \gamma \sin(v_0 - \Omega_0) = s_0 \tag{111}$$

the same as equation (100).

19 We shall now give LAPLACE's computation of dR. Equation (103) gives

$$ds = \gamma g dv \cos(gv - \Omega_0) \tag{112}$$

and if we refer the forces to the movable orbit and equinox, equation (16) will become

$$R = 2\frac{m}{r^3}s\sin fv = \frac{m}{r^3}\gamma\cos(gv - fv - \Omega_0) \tag{113}$$

retaining only the term depending on the longitude of the node. Equation (113) gives by differentiation

$$\left(\frac{dR}{dv}\right) = 2\frac{m}{r^3}fs\cos fv = \frac{m}{r^3}f\gamma\sin(gv - fv - \Omega_0) \tag{114}$$

$$\left(\frac{dR}{ds}\right) = 2\frac{m}{r^3}\sin fv. \tag{115}$$

Now since $dr = 0$, we need only equations (114, 115) to determine dR. If we therefore multiply (114) by dv and (115) by $ds = \gamma g dv \cos(gv - \Omega_0)$, and take the sum of the products, we get

$$dR = -\frac{m}{r^3}\gamma(g - f)dv\sin(gv - fv - \Omega_0) \tag{116}$$

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noticing only the term depending on the angle $gv - fv - \Omega_0$.

This gives by integration

$$\int \mathrm{d}R = \frac{m}{r^3}\gamma \cos(gv - fv - \Omega_0). \tag{117}$$

This is equal to the value of R in equation (113); and hence LAPLACE says "This term of δR gives, in $\int \delta \mathrm{d}R$, an expression exactly similar and equal to δR," *Méc. Cél.* [5363], δR taking the place of R in the notation of this article.

Now equation (113) gives

$$r\left(\frac{dR}{dr}\right) = -3\frac{m}{r^3}\gamma\cos(gv - fv - \Omega_0) \tag{118}$$

and if we substitute this and (117) in (53) we get, remembering that $a^3n^2 = \mu = 1$, and $r = a$,

$$\frac{dd\delta r}{dv^2} + \delta r - a\frac{m}{a^2}\gamma\cos(gv - fv - \Omega_0). \tag{119}$$

This is only *one-third* of the corresponding term in equation (65). If we now substitute $\int \mathrm{d}R$ and $\left(\frac{dR}{dr}\right)$ in equation (54) we get

$$d\delta v = -3\frac{m}{a^2}\gamma\, dv\cos(gv - fv - \Omega_0) \tag{120}$$

as in *Méc. Cél.* [5368]; and this is only *one-half* the value found for this term in equation (69).

20 We have seen that $\mathrm{d}R = 0$, in the undisturbed orbit, in so far as the terms depending on the longitude of the node are concerned; as is evident from equations (62); and we shall now show that it is also equal to nothing in the disturbed orbit. For we have by means of equation (111)

$$ds = ds_0 = \gamma\, g dv \cos(gv - \Omega_0) \tag{120'}$$

so that the term depending on $\left(\frac{dR}{ds}\right)$ is the same in both cases. But when we use the above value of ds_0, the differential of the independent variable, dv corresponds to the disturbed orbit; and in order that the same unit of measure may be used in the other term, $\left(\frac{dR}{dv}\right)$, we must substitute $dv_0 = gdv$, as is evident from equation (110), and then we shall get from equation (27) $\mathrm{d}R = 0$, and also $\int \mathrm{d}R = 0$. Therefore if we substitute $\int \mathrm{d}R = 0$, in equations (53, 54), and $r\left(\frac{dR}{dr}\right)$ (118) we shall get

$$\left.\begin{aligned} &\frac{dd\delta r}{dv^2} + \delta r - 3a\frac{m}{a^2}\gamma\cos(gv - fv - \Omega_0) \\ &d\delta v = -6\frac{m}{a^2}\gamma\, dv\cos(gv - fv - \Omega_0) \end{aligned}\right\} \tag{121}$$

which are the same as the corresponding terms of equations (65) and (69).

21 We have thus shown that $\mathrm{d}R = 0$ in the disturbed orbit by following LAPLACE's method of investigation; but we may prove the same thing in a much more elegant manner, as follows: Take equation (113)

$$R = \frac{m}{r^3}\gamma\cos(gv - fv - \Omega_0). \tag{122}$$

In this equation the angle $gv - fv - \Omega_0$ is nothing more than the negative of the longitude of the node in the disturbed orbit, referred to the movable equinox, as is evident from equation (102); we therefore have

$$R = \frac{m}{r^3}\gamma\cos\Omega \tag{123}$$

And as this value of R is not a function of the moon's longitude or latitude, we shall have

$$\left(\frac{dR}{dv}\right) = 0, \qquad \left(\frac{dR}{ds}\right) = 0 \tag{124}$$

and as $dr = 0$, equation (57) gives at once

$$\mathrm{d}R = 0. \tag{125}$$

ON THE NEW VARIABLE IN *SAGITTARIUS*.

6573

$18^h\ 14^m\ 2^s; -18°\ 54'.8$ (1875.0)

BY EDWIN F. SAWYER.

From a discussion of my observations of the above variable extending from September 22 to November 19, 1886 (the discovery of which was communicated in No. 145 of this Journal), I have determined the following provisional elements, subject to a revision from a more extended series of observations:

M = 1886 September 24.83 (Camb. M.T.) $+5^d.75$ E

Duration of increase = $1^d.80$

" " decrease = 3 .95

Limits of variation { Maximum $L = 11.8 = 5^M.6$
Minimum $L = 1.8 = 6\ .6$

The following observed times of maxima and minima have been determined by applying, to the times of each observation of the variable, the correction indicated by the comparison of its observed light with the mean light-curve readings given below. Values of $L > 6$ were used for determining maxima, the others for minima. The number of observations for deducing each phase are used in denoting the weight of the observation.

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Computed!

~~Observed~~ Maxima.

E	Camb. M.T.	Wt.	O – C
			d
0	1886 Sept. 24.83	1	+0.23
1	30.72	3	+0.15
2	Oct. 6.33	2	—0.08
4	17.83	1	—0.21
5	23.58	3	+0.27
7	Nov. 4.08	2	—0.18
8	9.83	1	+0.13
9	15.58	1	—0.22
10	21.33	1	+0.92

Computed!

~~Observed~~ Minima.

E	Camb. M.T.	Wt.	O – C
			d
0	1886 Sept. 23.03	1	—0.70
1	28.92	1	+0.38
2	Oct. 4.53	1	+0.09
3	10.28	1	+0.24
4	16.03	1	+0.23
5	21.78	3	—0.12
7	Nov. 2.28	2	+0.15
8	8.03	2	—0.28
9	14.70	1	+0.46
10	19.53	2	—0.08

The limited series of observations furnishes the following first approximation to the light-curve:—

Before Maximum.

d —2.0	$L = 1.8$	d —0.5	$L = 11.4$
—1.5	$L = 2.0$	—0.0	$L = 11.8$
—1.0	$L = 4.8$		

After Maximum.

d 0.0	$L = 11.8$	d 2.5	$L = 5.0$
+0.5	$L = 11.4$	3.0	$L = 3.2$
1.0	$L = 9.6$	3.5	$L = 1.8$
1.5	$L = 7.9$	4.0	$L = 1.8$
2.0	$L = 6.4$	4.5	$L = 2.9$

The light-curve exhibits a uniform and rather rapid increase, and a uniform and somewhat slow decrease.

Cambridgeport, 1886 *December* 13.

EPHEMERIS OF THE COMET 1886 *f* (*BARNARD, OCT. 4.*)

(*Continued from No.* 147.)

For Greenwich Midnight.

1886–7	α	δ	log r	log Δ	L	1887	α	δ	log r	log Δ	L
	h m s	° ′					h m s	° ′			
Dec. 27.5	19 12 10	+ 6 37.6	9.8465	0.1165	13.1	Jan. 17.5	32 52	— 4 20.7			
28.5	17 35	5 59.3				18.5	35 35	4 45.0			
29.5	22 47	5 21.6				19.5	38 14	5 8.2			
30.5	27 46	4 44.5				20.5	40 49	5 30.9	9.9877	0.2722	3.3
31.5	32 32	4 8.1	9.8656	0.1479	10.4	21.5	43 22	5 53.1			
Jan. 1.5	37 8	3 32.4				22.5	45 51	6 14.7			
2.5	41 34	2 57.3				23.5	48 17	6 35.8			
3.5	45 50	2 23.0				24.5	50 40	6 56.4	0.0122	0.2926	2.7
4.5	49 56	1 49.4	9.8878	0.1774	8.2	25.5	53 1	7 16.6			
5.5	53 54	1 16.6				26.5	55 19	7 36.3			
6.5	19 57 44	0 44.6				27.5	57 34	7 55.5			
7.5	20 1 25	+ 0 13.2				28.5	20 59 47	8 14.2	0.0359	0.3097	2.2
8.5	4 59	— 0 17.3	9.9120	0.2048	6.4	29.5	21 1 58	8 32.7			
9.5	8 27	0 47.2				30.5	4 7	8 50.6			
10.5	11 49	1 16.4				31.5	6 14	9 8.3			
11.5	15 5	1 44.7				Feb. 1.5	8 19	9 25.5	0.0588	0.3251	1.9
12.5	18 14	2 12.5	9.9372	0.2300	5.1	2.5	10 22	9 42.4			
13.5	21 19	2 39.5				3 5	12 23	9 58.9			
14.5	24 20	3 5.9				4.5	14 22	10 15.1			
15.5	27 14	3 31.5				5.5	21 16 20	—10 31.0	0.0807	0.3390	1.6
16.5	20 30 5	— 3 56.6	9.9626	0.2529	4.1						

Comparison with Prof. Frisby's obs. of Dec. 10 gives as the correction to this ephemeris at that date: $\Delta\alpha = -3^s.4$, $\Delta\delta = +7''$

NOVA ORIONIS.

By HENRY M. PARKHURST.

This star, discovered by Gore in December, 1885, nearly as bright as 6^M, diminished, according to my photometric measurements, nearly to the 10^M before the end of April, when it was lost in the sun's rays. When I next saw it, on October 22, it was brighter than in April; yet I did not anticipate any further increase in brightness, and did not look for it again until November 20, when the change was marked, and, in view of all precedent with regard to new stars, surprising. Since that time I have observed it on every clear evening with the results given in the appended table. In the preliminary reduction, the brightness of D.M. 20°, 1156 is assumed as $6^M.57$; and the other eight comparison-stars were determined by the ratio 2.512.

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	M		M
Oct. 22	9.21	Dec. 3	6.83
Nov. 20	7.13	7	6.52
21	6.81	8	6.32
26	6.91	9	6.47
27	6.72	10	6.38
28	6.90	11	6.42
29	6.88	16	6.60
Dec. 2	6.61	19	7.12

New York, 1886 *December* 20.

Each observation depends upon at least four extinctions of the variable, with two or more of each of, from two to seven, comparison-stars. In the later observations, the uncertainty of the amount of the correction for the effect of the illumination of the full moon upon the scale of the wedge, leaves the time of the maximum somewhat uncertain, but it has certainly passed.

OBSERVATIONS OF COMETS

MADE WITH THE 9.6 INCH EQUATORIAL AT THE U.S. NAVAL OBSERVATORY

By Prof. E. FRISBY.

(Communicated by the Superintendent.)

1886	Washington M.T.	*	No. Comps.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
				COMET 1886 e (FINLAY.)					
	h m s			m s	′ ″	h m s	° ′ ″		
Oct. 21	7 46 16.2	1	4 , 1	−1 1.20	− 3 46.1	18 16 4.60	−26 33 55.0	9.623	0.828
22	6 50 23.5	2	25 , 5	+1 53.20	+ 1 2.7	18 19 28.42	26 31 52.2	9.515	0.864
23	7 12 58.5	3	15 , 3	+1 14.58	+ 9 37.0	18 23 7.34	26 29 19.7	9.559	0.853
Nov. 18	7 56 34.3	4	20 , 4	−0 26.00	− 8 12.7	20 12 5.47	22 36 54.7	9.605	0.823
19	6 10 48.2	5	20 , 4	+1 1.06	− 2 4.8	20 16 28.15	22 20 46.6	9.360	0.871
26	6 50 56.7	6	20 , 4	+4 44.46	+ 3 19.3	20 50 31.00	20 0 35.8	9.460	0.851
27	6 37 1.6	7	20 , 4	−0 52.06	+ 3 30.3	20 55 26.02	−19 38 24.9	9.410	0.856
				COMET 1886 f (BARNARD, OCT. 4.)					
Nov. 1	17 11 44.2	8	25 , 5	−1 0.33	− 9 24.5	11 50 55.51	+ 6 46 20.2	n9.591	0.703
3	17 34 45.1	9	20 , 4	+3 44.42	+10 11.2	11 58 47.33	7 25 1.9	n9.566	0.694
Dec. 1	17 41 0.9	10	25 , 5	−1 26.93	− 8 37.0	15 20 43.19	17 53 13.2	n9.666	0.689
2	18 18 38.6	11	25 , 5	+1 40.40	− 3 10.4	15 32 3.91	17 58 55.8	n9.645	0.642
8	18 13 42.5	12	10 , 2	+1 30.27	− 3 14.2	16 39 1.82	17 17 11.2	n9.673	0.686
8	18 13 42.5	13	8 , 2	−0 36.77	+ 1 54.7	16 39 2.36	17 17 11.3		
9	18 8 39.8	14	25 , 5	−0 4.96	− 8 4.2				
9	18 21 1.3	15	15 , 3	−0 37.04	− 3 33.9				
10	18 12 13.8	16	20 , 4	+4 33.14	−10 13.7	17 0 29.68	+16 35 35.3	n9.677	0.701

Adopted Mean Places for 1886.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	18 17 4.05	+1.75	−26 30 16.9	+ 8.0	Yarnall
2	18 17 33.52	1.70	26 33 2.6	7.7	⅓(2 Yarnall + Arg.)
3	18 21 51.08	1.68	26 39 4.4	7.7	½(Yarnall + Arg.)
4	20 12 29.75	1.72	22 28 54.0	12.0	½(Arg. + Lamont)
5	20 15 25.37	1.72	22 18 53.9	12.1	Oe.Arg.
6	20 45 44.81	1.73	20 4 8.2	13.1	Oe.Arg.
7	20 56 16.31	1.77	−19 42 8.0	+12.8	Oe.Arg.
8	11 51 54.80	1.04	+ 6 55 53.8	− 9.1	½(Weisse + Schj.)
9	11 55 1.85	1.06	7 15 0.0	9.3	Am. Ephem.
10	15 22 9.52	0.60	18 1 52.8	2.6	Weisse
11	15 30 22.92	0.59	18 2 8.3	− 2.0	Weisse
12	16 37 31.02	0.53	17 20 21.9	+ 3.5	W.B. XVI 1128, 9
13	16 39 38.60	0.53	17 15 12.9	3.7	W.B. XVI 1205-8
14					DM. 17°, 3119
15					DM. 17°, 3117
16	16 55 55.94	+0.60	+16 45 44.1	+ 4.9	W.B. XVI 1648, 77, 8, 9

The right ascension of W.B. XVI 1648 is 50ˢ too small. The star is the same as 1677–79.

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OBSERVATIONS OF *U OPHIUCHI*, 1886. 6187

BY EDWIN F. SAWYER.

Only four minima of this star were observed during the year. ARGELANDER's method has been employed, as usual, in deducing the observed times (first column), using the mean light-curve formed from the 1883 observations.

The observed times of minimum, so found and given in the following table, have been compared with the elements given by CHANDLER in *Astr. Nachr.* 2448.

Observed Minimum, Camb. M. T.	Light Equation.	Heliocentric Observed Time.	Epoch.	Comp. Time from Chandler's Elements.	O—C
1886. d h m	m	d h m		d h m	m
June 30 11 2.5	+7.2	June 30 11 9.7	2157	June 30 11 23.5	—13.8
July 21 10 15.5	+5.7	July 21 10 21.2	2182	July 21 10 35.8	—14.6
Sept. 22 8 5.5	—1.7	Sept. 22 8 3.8	2257	Sept. 22 8 12.8	— 9.0
Oct. 8 7 0.5	—3 6	Oct. 8 6 56.9	2276	Oct. 8 6 54.4	+ 2.5

Mean correction of CHANDLER's elements, indicated by these observations, $-8^m.7$, corresponding to the mean epoch 2218.

Cambridgeport, 1886 *December* 8.

ON A NEW SHORT-PERIOD VARIABLE IN *CYGNUS*.

$20^h\ 37^m\ 43^s.7; +35^\circ\ 4'\ 3''$ (1855.0)

BY S. C. CHANDLER, JR.

Nearly a degree and a half north-preceding the known variable *T Cygni* is a pair of stars, 14′ distant from each other, forming a coarse, naked-eye double. Both of the components are ordinarily at the extreme limit of visibility, without optical assistance, when the sky is dark and clear;—that is from 6.6 to 6.8 magnitude. On October 3 last I estimated the north-following component to be the brighter by two-tenths of a magnitude; but on November 22 it was distinctly fainter by about the same quantity. A relative difference of four-tenths of a magnitude is too large to admit of mistake in properly made comparative estimates, and a few nights sufficed to establish the variability of the north following component. From a careful examination of my observations to this date the range of variation appears to be from $6^M.3$ to $7^M.6$, and the period a trifle over fourteen days. The elements

1886 Oct. 3.40 (Cambridge M.T.) + $14^d.04$ E

will probably prove to be very near the truth. Possibly the second decimal of the period may require a slight change. The increase of light occupies about four days; the decrease, ten days, with a halt in the latter about midway of its course.

Some difficulty has been experienced with the comparison-stars, having its origin, I think, in the variability of one of them. The publication of the list is therefore reserved until a more satisfactory scale can be formed, and doubtful points settled.

The position of the variable, by various authorities, is

	α 1875.0	δ
Ll. 40083	$20^h\ 38^m\ 30^s.20$	$+35^\circ\ 8'\ 24''.6$
Bessel; W. 1276	30 .24	11 .3
Leyden Zones	30 .64	18 .4
Armagh (2d) 2695	30 .60	18 .2
Adopted Place (1875.0)	20 38 30 .6	+35 8 18

corresponding to the place for 1855.0 given at the head of this article. It may be worth while to add that the star has a 9^M companion, $10^s.7$ following, and 1′ 43″ south, whose declination in Weisse's Bessel is 2′ too great.

Cambridge, 1886 *December* 13.

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THE

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ON THE STELLAR SPECTRA OF CLASSES I. *c* AND II. *b*.

By ORRAY T. SHERMAN.

It is customary to consider those spectra which exhibit bright lines, as divided into two classes. The one is represented by *β Lyrae* and *γ Cassiopeae*, in which the hydrogen-lines are distinctly visible, and the other, represented by the Wolfe and Rayet stars, in which are bright lines, not yet recognized as of hydrogen, and also dark lines. The stars in question, however, are no longer sharply divided by this classification. Both *β Lyrae* and *γ Cassiopeae* show at times a spectrum containing both bright and dark lines(1); and the bright lines of the stars of the Wolf and Rayet class probably belong to the low-excitation spectrum of hydrogen and the high-excitation spectrum of oxygen; a combination which is also found in the spectrum of *β Lyrae*(2). To display the evidence for this is the object of the following table. In the first column are given the recorded wave-lengths of the lines in question. When circumstances have permitted, these are referred to the same line, and the mean of the single observations is placed in the second column under the head "Accepted approximate value." The third column contains wave-lengths of prominent low-excitation hydrogen lines, as given by Hasselberg in his latest memoir(3). The fourth column adds the relative intensities of these lines. The fifth and sixth columns give the wave-lengths and intensities, for lines from the high excitation oxygen spectrum as given by Schuster(4). A glance will show that, excepting the intense band in the blue, and perhaps a single line in *R Geminorum*, all the lines in the stellar spectra are very near either to single intense lines or to a number of lines of middling intensity in the hydrogen-spectrum; while to the blue band no less than eleven intense lines in the oxygen correspond. Under the dispersion generally employed in faint-star spectra, the single lines would not be distinguished.

The combination of low-excitation hydrogen and high-excitation oxygen in a single spectrum may excite criticism, yet examples will not be wanting, and it has a physical significance. As unwonted, also, is the admission of varying relative intensity in lines of the same chemical origin, under the range of circumstances implied in the identical stellar spectrum; but examples are numerous, and the explanation is probably very simple. It will be considered more fully when discussing comet-spectra.

We may suggest that the difference between these two classes of stars lies essentially in the intensity of the interior light, in the intensity of atmospheric electrical excitation, and perhaps in the greater chemical complexity of that atmosphere.

(1) Vogel, *Bothkamper Beobachtungen*, Heft II., p 229.
E. von Gothard, *Astr. Nachr.* 2589, 2581.
Huggins, Report of the British Association, 1868, p 157.
Sherman, American Journal, Vol. XXX., and many unpublished observations.
(2) Sherman, American Journal, Feb. 1887.
(3) *Academia Petropolitana* (series VII.) Vol. XXX.
(4) Transactions of the Royal Society, 1880.

Observed Values of Wave-length $H\alpha$	Accepted approx. value $H\alpha$	Compared Spectra			
		Hydrogen λ	Hydrogen i	Oxygen λ	Oxygen i
$602 \pm L$, $604R$	603.	605.2	4		
		603.1	6		
		592.0	4		
$590 \pm d$	590.±	591.5	4		
		590.9	2–3		
A band from about 585 to		587.1	4		
580*k*		586.8	4		
		583.5	4		
583*a*, 582*b*, 582.4*k*, 582*c*	582.4	582.2	3–4		
581*h*, 580.5*b*, 581*R*, 580.9*d*, 580.5*c*, 580.9*e*, 581*k*	580.8	581.2	6		
579.5*a*, 578*b*	578.7	578.5	4		
575.3*f*	575.3	575.7	3–4		

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Observed Values of Wave-length $H\alpha$	Accepted approx. value $H\alpha$	Compared Spectra Hydrogen λ	i	Oxygen λ	i
		573.5	4		
573*g*	573.	572.9	4		
		572.6	4		
571*a*, 570*b*	570.5	570.2	3		
569*b*, 569*c*, 569.2*e*, 568*b*	568.8	568.8	4		
567.5*a*, 567*c*, 566.8*d*	567.1	567.1	2		
563*R*	563.	563.3	3		
559*b*	559.	559.5	3–4		
552*R*	552.	553.6	4		
		551.7	2–3		
545*k*	545.	543.4	3–4		
541*a*, 540*h*, 540*k*	540.3	540.0	2		
		539.8	2		
538*c*	538.	538.7	4		
		538.6	2		
536*a*, 536*b*, 536*b*	536.	537.2	2		
		536.5	2		
		536.6	2		
527*R*	527.	527.2	3		
		519.5	3–4		
		518.0	2		
517*R*	517.	517.4	2	517.5	3
		515.3	2	515.9	5
		514.6	2		
		514.2	2–3		
493**R*	493.	493.3	5	494.2	8
		493.1	2	492.3	6
		492.7	5		
486*a*, *k*	486.	486.0		485.6	4
		483.7	2–3		
482*R*	482.	482.2	2		
		481.3	2		
		479.6	3		
472**R*	472.	472.2	3		
A band from		471.8	4		
470*a*, 469*b*, 468*c*, 470*k*, 473*k*		472.2	3	470.9	6
to		471.8	4	470.4	10
465*a*, 466*b*, 461*c*, 461*k*, 467*k*		471.3	2	469.9	8
		470.8	2	467.5	8
or		468.9	2	466.1	8
described as (*a*) "*sehr hell und sehr breit, etwas*		468.3	3	464.9	4
verwaschen nach dem violett"				464.8	12
or (*b*) "*Mitte eines hellen Streifens*"				464.1	7
				463.7	6
				459.5	6
				459.0	6
468*a*, 467*b*, 467.5*c*, 469*h*	467.9	468.3	3	467.5	8
465.5*k*, 466*h*	465.8	466.0	2		
		465.2	2		
464*b*, 464.6*d*, 465.1*e*	464.6			464.9	8
				464.8	12
				464.1	7
463.6*g*, 463.3*f*	463.5	463.3	4–5		
		463.0	4		
		462.7	3–4		
460*R*	460.			459.5	6
				458.9	6

* "*Breit, verwaschen, nur zeitweilig sichtbar.*"

The letters refer to the stars as follows; the source of the observation accompanying each star.

L to *β Lyrae*, VOGEL, *Beobachtungen zu Bothkamp.* Heft 1., s 33.

R to *R Geminorum.* VOGEL, *Astr. Nachr.* Bd. 84, No. 2000, 120.

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a to *Durchmusterung* 35°,4001 } VOGEL, *Berichte der. k. Sächs. Gesellschaft* 1873, p 538.
b to *Durchmusterung* 35°,4013 } VOGEL, *Sitzungsberichte der k. Acad. d. Wissensch.* Wien.
c to *Durchmusterung* 36°,3956 } *Bd.* LXXXVIII., II. *abth.*, Oct. 1883.
d to γ *Argus*. COPELAND, *Copernicus*, Vol. III., p 205.
e to star, $\alpha = 16^h\, 46^m.7$, $\delta = -41°\, 37'.5$ (1883). COPELAND, *Copernicus*, Vol. III., p 205.
f to star, $\alpha = 13^h\, 10^m.6$, $\delta = -57°\, 31'$ (1883). " " "
g to star, $\alpha = 8^h\, 51^m$, $\delta = -47°\, 8'$ (1883). " " "
h OELTZEN'S ARGEL, 17681. } VOGEL. *Sitzungsberichte der. k. Acad. der Wiss.* Wien. Bd. LXXXVIII.
k LALANDE, 13412. } PICKERING, *Nature*, Sept. 23, 1880, April 28, 1881.

ANALYTICAL DETERMINATION OF THE INEQUALITIES IN THE MOON'S MOTION ARISING FROM THE OBLATENESS OF THE EARTH.

BY JOHN N. STOCKWELL.

PART IV.

22 We must now notice the effect of the terms arising from the sun's action. The disturbing function in this case is given by the equation, *Méc. Cél.* [5371],

$$R_1 = -\tfrac{1}{4}\frac{m'}{r'}r^2(1-3s^2) \qquad (126)$$

in which m denotes the sun's mass, and r' its distance from the earth. The variation of this function arising from any variation of s, which is the only quantity noticed by LAPLACE, is given by the equation, *Méc. Cél.* [5372],

$$(127) \qquad \delta R_1 = \left(\frac{dR_1}{ds}\right)\delta s = \tfrac{3}{2}\frac{m'}{r'^3}r^2 s\delta s.$$

Now in *Méc. Cél.* [5374, 5376] we have

$$(127') \qquad \frac{m'}{r'^3} = \frac{\overline{m}^2}{r^3}, \qquad \delta s = -\tfrac{4}{3}\frac{m}{\overline{m}^2 r^2}\sin fv$$

therefore (127) becomes

$$(128) \qquad \delta R_1 = -2\frac{m}{r^3}s\sin fv.$$

This value of δR_1 is equal to the value of R or R_0 arising from the earth's oblateness, as given by equation (113), and it has a contrary sign, so that the sum of the forces acting on the moon in any direction would be absolutely zero; and therefore if the sun's action makes $\delta s = 0$, as in equation (96), it must also make $\delta r = 0$, and $\delta v = 0$. It is therefore unnecessary to use equation (128) for finding δr and δv, as it would simply give the duplicate of equations (121) with contrary signs, and thus reduce the inequalities to zero.

23 LAPLACE's remark in *Méc. Cél.* [5398], that the inequality in the moon's latitude, arising from the oblateness of the earth, is only the *reaction* of the nutation of the earth's axis, discovered by BRADLEY, seems strangely at variance with mechanical principles, since the one has a period of only twenty-seven days while the other has a period of nearly nineteen years.

24 A singular fatality seems to have attended all LAPLACE's efforts to solve the problem under consideration. As another example in which a very remarkable result was obtained, we may refer to his calculation of the inequality of the latitude, in the appendix to the third volume of the *Mécanique Céleste*. He has there expressed the forces in terms of the elements instead of the coördinates; and the value of R is, *Méc. Cél.* [5962]

$$R = \frac{m}{a^3}q \qquad (129)$$

which is the same as given by the first term of the second member of equation (81); in which the values of p and q are given by equations (78). Now denoting the increments of p and q which arise from the disturbing forces, by δp and δq the differential variations of these increments are given by the equations (82), or *Méc. Cél.* [5790, 5791].

$$\left.\begin{aligned} d\delta p &= -\,andt\left(\frac{dR}{dq}\right) = -\,adv\left(\frac{dR}{dq}\right) \\ d\delta q &= \,andt\left(\frac{dR}{dp}\right) = \,adv\left(\frac{dR}{dp}\right) \end{aligned}\right\} \qquad (130)$$

Now equation (129) gives

$$\left(\frac{dR}{dp}\right) = 0, \qquad \left(\frac{dR}{dq}\right) = \frac{m}{a^3} \qquad (131)$$

therefore equations (130) become, *Méc. Cél.* [5963c]

$$d\delta p = -\frac{m}{a^2}dv, \qquad d\delta q = 0. \qquad (132)$$

These give by integration

$$\delta p = -\frac{mv}{a^2}, \qquad \delta q = 0 \qquad (133)$$

and the true values of p and q would be found by adding δp and δq to the values given by equations (78); namely

$$p = \gamma\sin\Omega - \frac{m}{a^2}v, \qquad q = \gamma\cos\Omega. \qquad (134)$$

If we substitute these values of p and q in equations (79) it gives

$$s = \gamma\sin(v-\Omega) + \frac{m}{a^2}v\cos v \qquad (135)$$

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which is the same as in equation (87). We may here observe that the other term of (87) arises from the part of R in (81) which has been neglected here.

Now, although LAPLACE gives the same values of $d\delta p$ and $d\delta q$ in *Méc. Cél.* [5963c, 5964, 5965] as we have given in (132), he yet finds

$$\delta p = 0, \quad \text{and } \delta q = -\frac{m}{a^2(g-f)} = \text{a constant};$$

and the values of p and q become, *Méc. Cél.* [5965e, 5965d] (135')

$$p = -\gamma \sin(gv - fv), \quad q = \gamma \cos(gv - fv) - \frac{m}{a^2(g-f)}$$

In other words, although the quantity p receives an increment, it yet remains unchanged; while q, which receives no increment, is increased by a constant! It is easy to discover *how* LAPLACE deduced this remarkable result, although it is difficult to give any logical reason for doing it.

25 LAPLACE resumes the subject of these inequalities in §5 of the sixteenth book of the *Mécanique Céleste*, for the purpose of carrying the approximations to a higher order of precision than he had done in his earlier investigations. He there gives the following equation for finding the inequality of the latitude

$$(136) \qquad \frac{dd\delta s}{dv^2} + g^2\delta s - 2\,H^{(2)}D^2 \sin\lambda \cos\lambda \sin fv = 0$$

in which we have omitted the terms of higher order, and a is put equal to unity. In this equation

$$(137) \qquad H^{(2)} = -(\alpha\rho - \tfrac{1}{2}\,\alpha\phi)$$

so that equation (136) may be written

$$(138) \qquad \frac{dd\delta s}{dv^2} + g^2\delta s + 2m \sin fv = 0$$

according to the notation of this article.

Now the second term of this equation evidently corresponds to the undisturbed orbit, while the angle fv corresponds to the disturbed orbit; but since the unit of measure is dv in the disturbed orbit the longitude in the undisturbed orbit will be $gv = \int gdv$, as in equation (110); therefore equation (138) should be

$$(139) \qquad \frac{dd\delta s}{dv^2} + g^2\delta s + 2m \sin fgv = 0$$

in which all the terms have the same unit of measure.

Equation (139) gives by integration, according to the general formula,

$$(140) \qquad \delta s = \frac{2m}{g^2(f^2-1)} \sin fgv = \frac{2m}{0} \sin fgv$$

being the same as before found in equation (98).

26 We may, however, render this last investigation much clearer by taking the element of time dt, which is wholly independent of the moon's coördinates, for the unit of measure, or independent variable. We shall therefore now examine PONTÉCOULANT's solution of the problem by this method.

PONTÉCOULANT deduces the inequality in the latitude from the following equation, *Théorie Analytiqué du Système du Monde*, tome IV, §106.

$$\frac{dd\delta z}{dt^2} + \frac{dz}{r^3} + \left(\frac{dR}{dz}\right) = 0 \qquad (141)$$

in which we have changed z to δz to indicate that it is a perturbation, and have also changed the sign of the last term in order that the forces may be measured in the same directions as in the preceding parts of this paper.

Now we have already found in equation (70)

$$\left(\frac{dR}{dz}\right) = \frac{1}{r}\left(\frac{dR}{ds}\right) = \frac{2m}{a^4} \sin fv \qquad (142)$$

in which we have put $\mu = 1$ and $r = a$. We shall first neglect the sun's action, and suppose the moon to move in a fixed ellipse having a mean distance a_0. Equation (141) will then become

$$\frac{dd\delta z}{dt^2} + \frac{\delta z}{a_0^3} + \frac{2m}{a_0^4} \sin fv_0 = 0. \qquad (143)$$

Now we have

$$\frac{1}{a_0^3} = n_0^2 \text{ and } v_0 = n_0 t \qquad (144)$$

and (143) becomes

$$\frac{dd\delta z}{dt^2} + n_0^2\delta z + \frac{2n_0^2 m}{a_0} \sin fn_0 t = 0. \qquad (145)$$

This gives by integration

$$\delta z = \frac{2m}{(f^2-1)a_0} \sin fn_0 t = \frac{2m}{0} \sin fn_0 t. \qquad (146)$$

Now let us take into account the sun's action, in which case the orbit is no longer fixed in position, nor has the same magnitude. Let the mean distance in the disturbed orbit be denoted by a and the longitude by v; then equation (142) will become

$$\frac{dd\delta z}{dt^2} + \frac{\delta z}{a^3} + \frac{2m}{a^4} \sin fv = 0. \qquad (147)$$

But we also have

$$\frac{1}{a^3} = n^2 \text{ and } v = nt \qquad (148)$$

and therefore

$$\frac{dd\delta z}{dt^2} + n^2\delta z + \frac{2n^2 m}{a} \sin fnt = 0 \qquad (149)$$

and by integration

$$\delta z = \frac{2m}{(f^2-1)a} \sin fnt. \qquad (150)$$

Suppose now that we require the perturbations in the undisturbed orbit in terms of the longitude in the disturbed orbit. The relations between a_0, a, and n_0, n, in these two cases are given by equations (105) and (109); namely

$$a_0 = a\,\{1 - \tfrac{1}{2}\,\overline{m}^2\}, \quad n_0 = n\,\{1 + \tfrac{3}{4}\,\overline{m}^2\}. \qquad (151)$$

If we substitute this value of n_0 in equation (145) it becomes

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$$\frac{dd\delta z}{dt^2} + n^2\{1 + \tfrac{3}{2}\,\overline{m}^2\}\,\delta z + \frac{2n^2\{1 + \frac{3}{2}\,\overline{m}^2\}\,m}{a\,\{1 - \frac{1}{2}\,\overline{m}^2\}}\sin f\,\{1 + \tfrac{3}{4}\,\overline{m}^2\}\,nt = 0 \qquad (152)$$

and this gives by integration (153)

$$\delta z = \frac{2m}{a\,(1 + \frac{1}{2}\,\overline{m}^2)(f^2 - 1)}\sin f\,(1 + \tfrac{3}{4}\,\overline{m}^2)[nt = v].$$

Lastly, suppose that we require the perturbations in the disturbed orbit in terms of the longitude in the undisturbed orbit as the independent variable.

We have from equations (151)

$$a = a_0\,\{1 + \tfrac{1}{2}\,\overline{m}^2\}, \quad n = n_0\,\{1 - \tfrac{3}{4}\,\overline{m}^2\} \qquad (154)$$

and if we substitute these in equation (149) it becomes

$$\frac{dd\delta z}{dt^2} + n_0^2\,\{1 - \tfrac{3}{2}\,\overline{m}^2\}\,\delta z + \frac{2n_0^2\,\{1 - \frac{3}{2}\,\overline{m}^2\}\,m}{a_0\,\{1 + \frac{1}{2}\,m^2\}}\sin f\,(1 - \tfrac{3}{4}\,\overline{m}^2)\,n_0t = 0. \qquad (155)$$

Therefore (156)

$$\delta z = \frac{2m}{a_0\,(1 + \frac{1}{2}\,\overline{m}^2)(f^2 - 1)}\sin f\,(1 - \tfrac{3}{4}\,\overline{m}^2)\,[n_0t = v_0].$$

All these values of δz given by equations (146, 150, 153, 156) differ from each other only by quantities of the order $m\overline{m}^2$; but they all become infinite by reason of the divisor $f^2 - 1 = 0$, the same as (98).

It is evident that PONTÉCOULANT's differential equation (m'), page 472, corresponds to equation (152) given above, except that he failed to notice that the angle fnt should be changed to $f(1+\frac{3}{4}\,m^2)\,nt$; and the same may be said in regard to LAPLACE's investigation in the fifth volume of the *Mécanique Céleste*.

27 To show the importance of attention to these angular functions we shall here observe that if we omit the factor of t which depends on $\overline{m}^2$ in equations (152) and (155), the resulting values of δz will have contrary signs. For these equations then become

$$(157) \qquad \frac{dd\delta z}{dt^2} + n^2\,(1 + \tfrac{3}{2}\,\overline{m}^2)\,\delta z + \frac{2\,n^2m}{a}\sin fnt = 0$$

$$(158) \qquad \frac{dd\delta z}{dt^2} + n_0^2\,(1 - \tfrac{3}{2}\,\overline{m}^2)\,\delta z + \frac{2\,n_0^2m}{a_0}\sin fn_0t = 0$$

in which we have also omitted the terms of the order $m\overline{m}^2$.

The first of these gives by integration

$$(159) \qquad \delta z = -\tfrac{4}{3}\,\frac{m}{a\overline{m}^2}\sin fnt$$

and the second gives.

$$(160) \qquad \delta z = +\tfrac{4}{3}\,\frac{m}{a_0\overline{m}^2}\sin fn_0t.$$

These values of δz have equal numerical values, but contrary signs; a result which might have been anticipated, when we consider the extreme sensitiveness to change, of quantities which are so near the border-line of indetermination, as indicated by equation (94).

We thus see that the consideration of the sun's action simultaneously with that of the earth, is simply equivalent to referring the perturbations to the *disturbed*, rather than the *undisturbed*, orbit; and we have already seen in Art. 18, that the interchange of these orbits does not affect the moon's latitude: much less therefore will it affect the perturbations arising from such insignificant forces as the ones under consideration.

28 Having now treated the subject of these inequalities so fully, it seems superfluous to add anything more in the way of mathematical development. We may however remark, in regard to PLANA's solution, which is given on page 145 of his *Theorie du Mouvement de la Lune*, tome I, that he should have added a constant to his integrals of the secular terms in the variation of the elements. Had he done so, he would have obtained the same results that we have given in equations (23).

29 As we have never made any computations by DELAUNAY's method of investigation, we shall restrict our remarks on Mr. HILL's *Supplement to* DELAUNAY's *Lunar Theory*, to a discussion of the results at which he arrived.

Mr. HILL has very carefully determined the coefficients of something more than *two hundred* inequalities in the moon's latitude, the greater part of which are very much less than 0″.1. The most remarkable feature, however, of these coefficients, is the analytical form under which they appear in the solution. By far the greater part of them have the quantity which we have denoted by $\overline{m}^2$ for a divisor. Now the quantity $\overline{m}^2$ varies inversely as the cube of the sun's distance from the earth; so that were the earth and moon in their present relations to each other, to revolve about the sun at twice the present distance of the sun from the earth, the principal inequality in the latitude would be eight times as great as at its present distance. The question then arises: What would be the perturbations of a satellite of a planet which revolved about the sun at the distance of *Neptune?* Were such hypothetical planet, the earth and moon in their present relations to each other, the sun's disturbing force would be so much diminished that the moon's periodic time would be shortened about *one-ninth* of a day, so that the time during which the disturbing force acts in the same direction would be about 86 minutes of time less than at present. It would therefore be logical to suppose that the amount of perturbation would be somewhat less than at its present distance. But Mr. HILL's formula would make the perturbation 27000 times greater than at present. In regard to this very absurd result, Prof. ADAMS comes to the rescue of Mr. HILL's formula by saying that "*he* (*I*) *applies it to a case in which it is not applicable, and for which it was not intended.*" It is true the formula, *the numerical formula*, was intended for the moon in its present relation to the earth and sun; but the general formula, (if it is really

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what it purports to be) is not restricted to the astronomical distance unity, but applies equally well to a planet and its satellite moving at any distance from the sun. In fact, the more distant the sun is, the more correct the formula ought to be.

Now I believe that Prof. ADAMS will admit that if a general method of development gives a correct result for a given distance of the sun, it will also give a correct result for a certain distance on each side of such given distance; and the only question now is to determine between what limits of distance the method is properly applicable. Fortunately for our purpose, Prof. ADAMS has given a criterion for determining such limits of distance. He says (using the notation of this paper), "If $\overline{m}$ have its usual meaning, and if m be a small positive constant depending on the ellipticity of the earth, then the value of the coefficient in question is approximately proportional to

$$\frac{m}{\overline{m}^2+m}.$$

Now, if, as in the case of our moon, m is very much smaller than $\overline{m}^2$ so that we may neglect the square of m compared with that of $\overline{m}^2$, the quantity just mentioned becomes approximately $=\frac{m}{\overline{m}^2}$ whereas if $\overline{m}^2$ is small compared with m the same quantity becomes nearly $=1$, and the coefficient becomes nearly independent of the ellipticity of the earth, as it should do, since in this case the coefficient of this term is approximately equal to the sine of the obliquity of the ecliptic."

It follows from this criterion, if I rightly understand it, that the *form* of development adopted by Mr. HILL is applicable to all cases in which m is *less* than $\overline{m}^2$. Now, although I am unable to discover any logical reason for such a criterion, I am willing to abide by its verdict in the present case. For we have in the actual relations of the sun, moon and earth, $\overline{m}^2 = 1154''.0973$, $m = 0''.03308$; whence it follows that $\overline{m}^2$ is about 35000 times as large as m. And were the earth and moon in their present relations to each other, to revolve around the sun at the distance of *Neptune*, we should have $\overline{m}^2 = 0''.04275$, while m would remain unchanged; so that according to Prof. ADAMS' criterion Mr. HILL's formula *ought* to apply to the hypothetical case, although he says that it does not.

On the other hand, suppose $\overline{m}^2$ to be very much smaller than m. Then we should have a coefficient of disturbance wholly independent of the disturbing function; a conclusion that seems widely at variance with well established mechanical principles; namely, that an effect is proportional to its cause.

Suppose again that the earth and moon were to revolve around the sun at *one-half* their present distance, the value of $\overline{m}^2$ would have eight times its present value, and this inequality, which is at present supposed to be about $8''$, would be reduced to a single second. We have thus applied the general formula for the perturbation of the latitude to a number of hypothetical cases in which the conditions of disturbance differ considerably from the actual; because a formula can often be shown to be erroneous, more conveniently and satisfactorily by showing that it fails in extreme cases, than in any other way.

30 In my review of HILL's *Supplement to Delaunay*, I stated the fact that he had omitted the last three terms of equation (9), in his computation of the forces depending on the product of the disturbing masses. Prof. ADAMS, while admitting this fact, remarks that the spirit of DELAUNAY's method is such that it is not necessary to notice these terms. To this I would say that DELAUNAY's method in his own hands shows no power to estimate the effects of forces by entirely ignoring them. It is also certain that the value of δR derived from these terms by using Mr. HILL's value of δs would be equal to $-R_0$, as in equation (128), so that the effect of these terms would be to reduce the whole perturbation to nothing. It thus agrees with LAPLACE's method in its results, if not in its spirit.

31 We are now prepared to determine the value of δR in equation (9). If we neglect the sun's coördinates, we may take the following values of the perturbations due to the sun's action from the *Theory of the Moon's Motion;* namely, (161)

$$\delta_1 r = -\tfrac{1}{8}\,a\,\frac{\overline{m}^2}{\mu},\qquad \delta v = 0,\qquad \delta_1\theta = \tfrac{1}{2}\tfrac{1}{4}\,\frac{\overline{m}^2}{\mu}\,\gamma\sin(nt-\Omega)$$

Then taking for $\left(\frac{dR_0}{dr}\right), \left(\frac{dR_0}{dv}\right), \left(\frac{dR_0}{d\theta}\right)$ the values given by equations (17), we find

$$\delta R_0 = a\,\frac{m\overline{m}^2}{r^4}\sin\theta\cos\theta\sin v + \tfrac{1}{1}\tfrac{1}{2}\,\frac{m\overline{m}^2}{r^3}\,\gamma\sin(nt-\Omega)\{\cos^2\theta-\sin^2\theta\}\sin v. \tag{162}$$

In order to find the last three terms of equation (9) we have

$$R_1 = -\tfrac{1}{4}\,\frac{m'}{a'^3}\,r^2\{1-3\sin^2\theta\} \tag{163}$$

in which m' and a' denote the sun's mass and mean distance. We also have according to equations (21, 35, 41), neglecting constant and secular terms,

$$\delta_0 r = \tfrac{1}{3}\,\frac{m}{a}\,\gamma\cos(2nt-\Omega),\qquad \delta_0 v = \tfrac{5}{12}\,\frac{m}{a^2}\,\gamma\sin(2nt-\Omega),\qquad \delta_0\theta = -\tfrac{1}{2}\,\frac{m}{a^2}\sin nt. \tag{164}$$

Equation (163) gives

$$\left(\frac{dR_1}{dr}\right) = -\tfrac{1}{2}\,\frac{m'}{a'^3}\,r\{1-3\sin^2\theta\},\qquad \left(\frac{dR_1}{dv}\right) = 0,\qquad \left(\frac{dR_1}{d\theta}\right) = \tfrac{3}{2}\,\frac{m'}{a'^3}\,r^2\sin\theta\cos\theta \tag{165}$$

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The last three terms of equation (9) therefore become

$$\delta R_1 = -\tfrac{1}{8}\frac{mm'}{aa'^3}\gamma\cos(2nt-\Omega)\{1-3\sin^2\theta\}r - \tfrac{3}{4}\frac{mm'}{a^2a'^3}\sin ntr\cdot{}^2\sin\theta\cos\theta \qquad (166)$$

Therefore the complete value of δR is

$$\left.\begin{aligned}\delta R = a\frac{m\overline{m}^2}{r^4}\sin\theta\cos\theta\sin v + \tfrac{17}{12}\frac{m\overline{m}^2}{r^3}\gamma\sin(nt-\Omega)\{\cos^2\theta-\sin^2\theta\}\sin v\\ -\tfrac{1}{8}\frac{mm'}{aa'^3}\gamma\cos(2nt-\Omega)\{1-3\sin^2\theta\}r-\tfrac{3}{4}\frac{mm'}{a^3a'^3}\sin nt\cdot r^2\sin\theta\cos\theta\end{aligned}\right\} \qquad (167)$$

If we take the partial differential coefficients of this function with respect to r, v, and θ, and put $r=a$, $v=nt$, and $\sin\theta=\gamma\sin(nt-\Omega)$, $\cos\theta=1$, *after* the differentiation, we shall obtain the increments to be added to equations (19) in order to allow for the terms depending on the products of the disturbing functions, as follows; observing also that $\overline{m}^2=\dfrac{m'a^3}{a'^3}$

$$(168)\begin{cases}\delta\left(\dfrac{dR}{dr}\right)=\tfrac{113}{24}\dfrac{m\overline{m}^2}{a^4}\gamma\cos(nt\ \Omega)-\tfrac{39}{8}\dfrac{m\overline{m}^2}{a^4}\gamma\cos\Omega\\ \delta\left(\dfrac{dR}{dv}\right)=\tfrac{29}{24}\dfrac{m\overline{m}^2}{a^3}\gamma\{\sin(2nt-\Omega)-\sin\Omega\}\\ \delta\left(\dfrac{dR}{d\theta}\right)=\dfrac{m\overline{m}^2}{a^3}\sin nt-\tfrac{3}{4}\dfrac{m\overline{m}^2}{a^3}\sin nt=\tfrac{1}{4}\dfrac{m\overline{m}^2}{a^3}\sin nt\end{cases}$$

Equation (166) gives the increment of the disturbing function arising from the sun's action. If we take its differential coefficient with respect to θ we shall have

$$(169)\qquad \delta\left(\frac{dR}{d\theta}\right)=-\tfrac{3}{4}\frac{m\overline{m}^2}{a^3}\sin nt.$$

And if we add this to the third of equations (19) we get its corrected value as affected by the sun's action; namely,

$$(170)\qquad \left(\frac{dR}{d\theta}\right)=2\frac{m\mu}{a^3}\left\{1-\tfrac{3}{8}\frac{\overline{m}^2}{\mu}\right\}\sin nt.$$

If we therefore multiply the second member of equation (21) by $1-\tfrac{3}{8}\dfrac{\overline{m}^2}{\mu}$ we shall get the corrected value of $\delta\theta$ depending on the sun's action. The sun's action therefore adds to the inequality in the latitude the quantity.

$$(171)\qquad \delta\delta\theta=+\tfrac{3}{16}\frac{m\overline{m}^2}{a^2\mu}\sin nt.$$

In equation (99) we have the term $-\tfrac{1}{4}(g^2-1)\,H$ arising from the sun's action. But $\tfrac{1}{4}(g^2-1)=\tfrac{3}{8}\,\overline{m}^2$ and since $H=-\tfrac{1}{2}\dfrac{m}{a^2}$ the preceding term becomes

$$(172)\qquad -\tfrac{1}{4}(g^2-1)\,H\sin fv=+\tfrac{3}{16}\frac{m\overline{m}^2}{a^2}\sin fv=\delta\delta s;$$

agreeing exactly with equation (171); so that LA PLACE's differential equation of the latitude, when correctly integrated gives the same value as my own method.

But we see by the third of equations (168) that when we notice all the terms of the order $m\overline{m}^2$ the correct value of $\left(\dfrac{dR}{d\theta}\right)$ is

$$\left(\frac{dR}{d\theta}\right)=2\frac{m\mu}{a^3}\{1+\tfrac{1}{6}\frac{\overline{m}}{\mu}\}\sin nt. \qquad (173)$$

so that the effect of these terms in the expressions of the forces is to add to the inequality the term

$$\delta\delta\theta=-\tfrac{1}{16}\frac{mm^2}{a^2\mu}\sin nt=-0''.0000116\sin nt. \qquad (174)$$

This little calculation shows how utterly insignificant these terms of the order $m\overline{m}^2$ are: and we shall not give the complete development of the effect of these terms upon the moon's coördinates. We may however observe that the term $-\tfrac{39}{8}\dfrac{m\overline{m}^2}{a^4}\gamma\cos\Omega$, in equation (168) would have the effect to increase the coefficient of δv in the ratio of

$$1+\tfrac{13}{8}\frac{\overline{m}^2}{\mu}:1;\ \text{or as } 1.009:1.$$

32 If we now assume the earth's oblateness to be $\frac{1}{289}$, the inequalities in the longitude and latitude will become

$$\begin{aligned}\delta v&=0''.00134\sin(2nt-\Omega)+5''.242\{\sin\Omega-\sin\Omega_0\}\\ \delta\theta&=-0''.01785\sin nt.\end{aligned}\qquad (175)$$

According to the preceding calculations the moon's inequality in latitude is wholly insensible, and the inequality in the longitude is less than the value found by other investigators in the ratio of 13: 19. This diminution of the equation in the longitude may perhaps explain the origin of the empirical equation discovered by Prof. NEWCOMB, the cause of which has been vainly sought for in the action of the planets upon the moon.

33 The preceding calculations are in accordance with the general considerations introduced at the beginning of this paper; and if they are correct, it follows that mathematicians and astronomers have been deceiving themselves during nearly a hundred years, by the use of equations in the moon's latitude and longitude which were derived from an indeterminate equation, and which have therefore no necessary physical existence. This is the most extensive, interesting, and important case of mathematical legerdemain to be found in the whole history of science; and it is believed that by eliminating the effects of these erroneous equations from the elements of the moon's orbit, and from the theory of her motion, tables of greatly increased accuracy can be constructed, and the general improvement of the lunar theory be thereby greatly promoted.

Cleveland, Ohio, 1886 *August* 3.

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ON A NEW VARIABLE OF THE *ALGOL* TYPE.

$20^h\ 46^m\ 16^s.1$; $+34°\ 6'\ 57''$ (1855.0).

BY S. C. CHANDLER, JR.

In No. 148, p 32, of this Journal, I alluded to the possible variability of one of the comparison-stars employed with the variable there mentioned. I now beg to announce that the star, whose place is above given, is a variable of the *Algol* type, thus making the eighth of this class so far discovered.

Leaving the details with regard to the discovery, and the observations so far obtained, to be communicated in the next number, I will merely say that they indicate the following times of

OBSERVED MINIMA.

1886	Dec.	9^d	6^h	15^m	Camb. M.T.
		21	6	12	
		27	6	0	

which, neglecting for the present the light-equation, furnish the approximate elements

$$1886 \text{ Dec. } 9^d.260 \text{ Camb. M.T.} + \left(\frac{5^d.997}{n} E\right)$$

To determine what aliquot part of $5^d.997$ is the true period, we can first exclude the hypotheses that $n = 3$ or $n = 5$, or any multiples thereof, as conflicting with observations on various dates when the star was seen at its maximum brightness. There remain then the hypotheses

$$\begin{array}{lll} n = 1 & \text{or} & P = 5^d.9970 \\ n = 2 & & P = 2.9985 \\ n = 4 & & P = 1.4992 \\ n = 7 & & P = 0.8567 \\ n = 8 & & P = 0.7496 \end{array}$$

Unfortunately, the choice between these cannot be immediately settled — for a month or so at least — by observations in the eastern portion of the United States; although it might easily be done in Europe or on the Pacific coast. I strongly surmise, however, that the period will prove to be $1^d.4992$. The ground of this presumption rests on a relation which, it seems to me, can be recognized in the ratio of the actual duration of the light-fluctuations of the *Algol* stars to their whole periods; and which is exhibited in the following table of all the known variables of this type.

Star	Period	Duration of Oscillations	Ratio
U Ophiuchi	$20^h.13$	$5^h.0$	0.248
δ Librae	55 .85	12 .0	0 214
U Cephei	59 .82	10 .0	0.167
Algol	68 .81	9 .15	0.134
U Coronae	82 .85	9 .75	0.118
λ Tauri	94 .87	10 .0	0.105
S Cancri	227 .63	21 .5	0.094

My observations show that the whole light-increase occupies not more than three hours, so that the whole duration of the oscillation, assuming the light-curve to be symmetrical, is probably about six hours. Consequently, a period as great as three days, or very much less than one day, would render this star exceptional in respect to the relation above noticed. Therefore I anticipate with some confidence the confirmation of the period $1^d\ 11^h\ 59^m$, or, if not that, then $20^h\ 34^m$, or possibly $18^h\ 6^m$. Similarly considerations guided me once before, in the case of *U Ophiuchi*, successfully to the true period.

The light of the variable ranges from $7^M.1$ to $7^M.8$. The inferior limit is as yet uncertainly determined.

I can find no observations of position except in the DM., and one observation in LALANDE.

Cambridge, 1886 *December* 29.

NEW ASTEROID.

An "Associated Press" despatch, of December 23, announces the discovery of Asteroid No. 264, by Dr. C. H. F. PETERS, of Clinton, N. Y., in the position

1886, December 22, $10^h\ 50^m$ Wash. M.T. $\alpha = 1^h\ 14^m\ 20^s$ $\delta = +5°\ 53'\ 50''$

Daily Motion $+28^s$ in α, and $8'$ northward; $11\frac{1}{2}^M$.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 150.

VOL. VII. BOSTON, 1887 JANUARY 19. NO. 6.

NOTE ON MR. STOCKWELL'S "ANALYTICAL DETERMINATION OF THE INEQUALITIES IN THE MOTION OF THE MOON ARISING FROM THE OBLATENESS OF THE EARTH."

BY PROF. A. HALL.

It does not seem to me that the exposition of the method of LaPlace, given in this Journal, No. 148, p 27, is correct. If we take Mr. Stockwell's equation (92) and make no assumption on the value of the constants, we find:

$$H = -\frac{2m}{a^2}\cdot\frac{1}{g^2-f^2}$$

$$\delta s = -\frac{2m}{a^2}\cdot\frac{1}{g^2-f^2}\sin fv.$$

Substituting the values of the constants:

$$g = 1.00402175,\quad f = 1.00000290,\ \text{etc.}$$

$$\delta s = -6''.479 \sin fv$$

agreeing with LaPlace, who found the coefficient -6.487 in sexagesimal seconds. The method followed in the *Mécanique Céleste* is to put $f = 1$ in the above value of δs, and then to write $g^2 - 1 = (g+1)(g-1) = 2(g-1)$, since g is so nearly equal to unity.

From this example we may infer, I think, that it is not safe to assume special values of the constants during our analytical transformation. We should wait until we have obtained the final result, and then introduce particular values of the constants. This is what LaPlace has done.

1886 *December* 30.

NOTES ON COMET 1886 *f* (*BARNARD, OCT. 4.*)

BY E. E. BARNARD.

October 4. The comet was discovered at about 17^h, with 5 in. refractor. It was bright, round and much condensed. Two equatorial pointings on it were obtained with the 6 in. telescope as it was fading from view, giving the place:

1886 *Oct.* 4. $17^h\ 11^m\ 41^s$ Nashville M.T.

$\alpha = 10^h\ 36^m\ 8^s \qquad \delta = +0°\ 57'.6$

The following observations are all made with 6 in. equatorial:

October 5. Faint diffused tail; difficult small nucleus.

October 6. Suspected fainter, nucleus difficult; not sure of any tail.

October 8. Less bright.

October 10. Bright, though probably less than at first observation. Small and difficult nucleus.

October 12. Bright, much condensed, with small nucleus; full moon.

October 16. Bright, large and strong condensation, signs of brush-like tail preceding.

October 18. Brightly condensed to difficult nucleus. Diffused tail.

October 19. Very bright and large, with strong brushy tail preceding. Nucleus = $8\frac{1}{2}^M$ probably, and better seen than at any previous observation. Half-moon.

October 22. Large and bright with indefinite condensation to almost a nucleus; faint traces of tail.

October 24. Large and bright. Broad brushy short tail, not very distinct. Indefinite nucleus. The head is developing a symmetrical form.

October 29. Much larger and brighter; uncertain of nucleus, but very strongly condensed. Large brushy tail, suspected to be bifurcated. It is now visible to the naked eye as an ill-defined spot of light.

October 31. As easy to naked eye as a sixth mag. star. Not quite so large in telescope as at last observation, but very bright. There are now visible two tails. From sketch these tails were found to be approximately at position-angles

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287° and 134°. The first being the longer and brighter. For future designation these tails will be called N and S, respectively; N being the northern and S the southern tail. The space between the tails was entirely free from nebulosity. N was about $2\frac{1}{2}°$ long, while S was not quite $\frac{1}{2}°$. A slight bulging of the head of the comet, at the position-angle 150°, seemed to indicate the probable formation of a third tail.

November 3. Very bright, with ill-defined nucleus. The two tails again visible; N traceable for 2° or 3°. Cannot verify the elongation as $p = 150°$, but there is suspicion of faint prolongation there. Easy to the naked eye as a brightish spot of haze.

November 4. Brightish to eye, but no elongation seen. Telescopically, very bright and the head better defined; nucleus decidedly stellar. The tails are quite easy; N is at least 2° long. Sky poor.

November 6. Brightish to naked eye, and faint extension away from sun as noticeable as a fifth mag. star. Telescopically, N brighter and easily traceable for $2\frac{1}{2}°$; S about $\frac{1}{2}°$ long. Nucleus very stellar and bright; slightly yellowish. Head forming well, though outline not very definite yet. Again suspect slight bulging-out of head at 150°, probably a slight projection at that point. Sky fine.

November 7. Much easier to naked eye—quite noticeable, with faint tail. In telescope, the two tails conspicuous; N longer than S, as usual, and brighter; N seems to be the main tail. S longer and brighter than before. Sky good.

November 12. Bright and large in telescope. Full moon. In this observation the filar-micrometer with bright field-threads was used on the comet, for the first time.

November 14. Easily visible to naked eye, just above *E Virginis*. Moon just past full.

November 18. As bright to the eye as a fourth mag. star.

November 23. Decidedly noticeable to eye, and of at least fourth mag. A slender train traceable for at least 7° or 8°. A splendid object in the telescope. Three tails are now visible, a third having formed between N and S, nearer to N. The new tail is probably about $\frac{1}{4}°$ long. These three are entirely distinct, with dark sky between them. N traced for a great distance, and is very peculiar; — slender where it leaves the head, it widens as the distance increases. At $1\frac{1}{2}°$ from the head it suddenly diffuses very much on its north side, but the south side is remarkably well defined; the tail at the above distance is about $\frac{1}{4}°$ broad. The nucleus is bright, slightly yellowish, almost stellar, surrounded by yellowish haze. Sky fine.

November 25. Bright to eye; tail not so well seen as at last observation, but can trace it beyond *Arcturus*. Telescopically, the comet is a splendid object; N and S are much brighter and better defined. Tracing along N, the part that was so well defined at last observation is found to have lost its sharp outline, while the south side is better defined—almost a reversion of the conditions at last observation. The middle tail, though well seen, can now scarcely be

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These are so far the most important of my notes of the comet. The observations have been made with a comet eye-piece, giving a power of about 40, and the ring eye-piece, giving about 80. The dates are astronomical, all the obser-[va]tions having been made between 16^h and dawn. At nearly every observation the comet has been observed for position either with the ring or filar-micrometer; these positions when all reduced will be published, but it has been thought that these physical observations might be of value without the positions.

[Va]nderbilt University Observatory,
Nashville, Tenn., 1886 *December* 6.

ON THE ORBIT OF THE PERIODIC COMET 1886 *e* (FINLAY)

BY LEWIS BOSS.

make a preliminary examination of the ques-
[ti]y between the comet of FINLAY and that
DEVICO in 1844, I have computed the elements
If the resulting ephemeris shall enable
[s]ect comparison-stars in advance, and thus to
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$\log e = 9.8564611$
$\log a = 0.5496395$
$\log q = 9.9990304$
$\log \mu = 2.7255474$

Approx. period $6^y.675$

The corrections necessary to reduce these elements to the ecliptic and equinox of 1887.0 are:

$$\Delta\pi = +50''.25,\quad \Delta\Omega = +42''.30,\quad \Delta i = +0''.23$$

The equations of the coordinates for the respective years are:

$$1886.0\begin{cases} x = [n9.9996185]\,(v+97^\circ\ 30'\ 42''.5) \\ y = [n9.9562858]\,(v+\ 8\ \ 38\ \ 47\ .1) \\ z = [n9.6325231]\,(v+\ 2\ \ 26\ \ 50\ .9) \end{cases}$$

$$1887.0\begin{cases} x = [n9.9996185]\,(v+97^\circ\ 31'\ 32''.8) \\ y = [n9.9562881]\,(v+\ 8\ \ 39\ \ 38\ .0) \\ z = [n9.6325145]\,(v+\ 2\ \ 27\ \ 37\ .5) \end{cases}$$

The normal places are thus represented:

	C—O $\Delta\lambda$	C—O $\Delta\beta$
Sept. 30.5	0''.0	0''.0
Oct. 23.0	+0 .6	[—2 .9]
Nov. 19.5	+0 .9	[—3 .4]
Dec. 19.0	0 .0	0 .0

In order to investigate more fully the character of the discrepancies between calculation and observation, I have prepared the subjoined table, including in it nearly all the observations made at the Dudley Observatory, with such others as could conveniently be included without calculation of additional ephemeris-dates.

	Place	$\Delta\alpha$	$\Delta\delta$
September 29	*Rome	+0.29	+ 7.1
	*Nice	—0.57	+ 1.3
	*Lyons	—0.20	— 3.1
	*Albany	—0.48	— 1.9
	*Nashville	+0.69	— 6.1
September 30	*Vienna	+0.91	+ 3.9
	*Lyons	+0.71	+ 0.4
	*Washington	—0.04	— 1.5
October 1	*Vienna	—0.24	—14.1
	*Rome	+0.14	—10.8

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287° and 134°. The first being the longer and brighter. For future designation these tails will be called N and S, respectively; N being the northern and S the southern tail. The space between the tails was entirely free from nebulosity. N was about $2\frac{1}{2}°$ long, while S was not quite $\frac{1}{2}°$. A slight bulging of the head of the comet, at the position-angle 150°, seemed to indicate the probable formation of a third tail.

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November 4. Brightish to eye, but no elongation seen. Telescopically, very bright and the head better defined; nucleus decidedly stellar. The tails are quite easy; N is at least 2° long. Sky poor.

November 6. Brightish to naked eye, and faint extension away from sun as noticeable as a fifth mag. star. Telescopically, N brighter and easily traceable for $2\frac{1}{2}°$; S about $\frac{1}{2}°$ long. Nucleus very stellar and bright; slightly yellowish. Head forming well, though outline not very definite yet. Again suspect slight bulging-out of head at 150°, probably a slight projection at that point. Sky fine.

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November 25. Bright to eye; tail not so well seen as at last observation, but can trace it beyond *Arcturus*. Telescopically, the comet is a splendid object; N and S are much brighter and better defined. Tracing along N, the part that was so well defined at last observation is found to have lost its sharp outline, while the south side is better defined—almost a reversion of the conditions at last observation. The middle tail, though well seen, can now scarcely be separated from N as the blending of the latter has almost reached the middle tail.

November 26. Head bright to naked eye. The tail, though scarcely noticeable, is easily traceable as high as *Arcturus;* the light of this star deadens the eye to the feeble light of the train. The comet is more conspicuous than a fourth mag. star. Telescopically, it is a fine object; the two old tails clear and distinct, N longer and brighter than S, as at all former observations. The middle tail has utterly disappeared, having doubtless coalesced with N. Nucleus stellar and bright, slightly yellowish, but not well defined. Tail traceable for about 5° beyond *Arcturus*, its axis passing 0°.6 to the north of that star. The axis of N passes through nucleus, but that of S noticeably passes north of nucleus, and its south border cuts through the nucleus if prolonged. The head, as noticed at former observations, is larger than at the junction of the tails, giving it the appearance of having a neck, from which the tails spring. N is narrowest near head and is symmetrical with head and nucleus, while the head looks "lop-sided" with reference to S. Everything indicates that N is the main tail.

November 28. Bright to eye and fully as noticeable as ζ *Bootis*. Slender tail (not bright) traced for about 12°. With the telescope, N and S are conspicuous objects. Cannot trace S more than $1\frac{1}{4}°$. No trace of the middle tail. Nucleus bright and star-like, but it diffuses with high powers.

November 29. Head is as bright to naked eye and more noticeable than ϵ *Bootis*. Tail not bright but can easily trace it to the line between ϵ and α *Bootis*, passing several degrees to right of ϵ. With telescope, the head is very bright. The two tails brighter and better defined. There is a narrow ray of light running along the axis of N from nucleus; it is quite sharp and definite. Sky good. The space between N and S is now filling with nebulosity. Previous to this no nebulosity has been seen, though looked for, in this space. Nucleus small but planetary, having a perceptible diameter; and faintly yellowish, with dense haze about it. The ray of light and main tail are symmetrical with nucleus, but S is not so.

December 1. Head very bright, and tail slender, straight and decidedly noticeable; it is fully 10° long and telescopically very bright. The head is better formed, having lost that neck-like appearance, and the tails flowing symmetrically from the head. The bright ray, so conspicuous at last observation, does not now exist. Both tails brighter and the south one longer than before. The interior space is decidedly filling with haze, and the tails coalesce at a greater distance from head. Nucleus bright but not stellar.

December 5. The comet is very noticeable. Tail very straight and slender, but not bright, 10° long. The telescopic aspect as previously, so far as could be determined—dawn having affected the comet before the telescope was turned on it.

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These are so far the most important of my notes of the comet. The observations have been made with a comet eye-piece, giving a power of about 40, and the ring eye-piece, giving about 80. The dates are astronomical, all the observations having been made between 16^h and dawn. At nearly every observation the comet has been observed for position either with the ring or filar-micrometer; these positions when all reduced will be published, but it has been thought that these physical observations might be of value without the positions.

Vanderbilt University Observatory,
Nashville, Tenn., 1886 *December* 6.

ON THE ORBIT OF THE PERIODIC COMET 1886 *e* (*FINLAY*)

BY LEWIS BOSS.

In order to make a preliminary examination of the question of identity between the comet of FINLAY and that discovered by DEVICO in 1844, I have computed the elements here presented. If the resulting ephemeris shall enable observers to select comparison-stars in advance, and thus to improve many opportunities for observation that would otherwise be lost, that will in part justify what might seem to be an amount of work disproportioned to the resulting advantage.

In the formation of the following normal places upon which the calculation of elements depends, I have had in view the detrimental effect of even comparatively small errors of observation upon the resulting orbit. While the position of the comet of 1844 was relatively favorable for the computation of accurate elements, the space relations of the FINLAY comet are extremely unfavorable. In combining the observations for normal places, I have used weights derived from various considerations,—such as character of star-place, number of comparisons and size of telescope. Following are the places for the mean equinox of 1886.0 with the number of observations included in each:

1886	α	δ	No. Obs.
Sept. 30.5	258° 3′ 49″.4	−26° 16′ 38″.4	12
Oct. 23.0	275 18 49 .8	−26 30 44 .7	8
Nov. 19.5	304 8 56 .6	−22 20 28 .0	7
Dec. 19.0	341 22 39 .0	− 8 46 6 .3	8

In the table of comparisons with observation, to be given later, the composition of these normal places is indicated by asterisks attached to the observations so used. In the calculation I employed the same method as in my former papers upon this comet (see *Astr. Journ.* Nos. 145 and 147), which is the very elegant method of the late Dr. OPPOLZER, and in which the two middle latitudes are neglected. Following are the elements resulting from a series of approximations followed by an interpolation, and a further recomputation.

$$T = 1886 \text{ November } 22.38816 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \pi &= 7°\ 33'\ 2''.0 \\ \Omega &= 52\ \ 26\ \ 14\ .3 \\ i &= 3\ \ \ 1\ \ 46\ .4 \end{aligned}\right\} 1886.0$$

$$\begin{aligned} \log e &= 9.8564611 \\ \log a &= 0.5496395 \\ \log q &= 9.9990304 \\ \log \mu &= 2.7255474 \end{aligned}$$

Approx. period $6^y.675$

The corrections necessary to reduce these elements to the ecliptic and equinox of 1887.0 are:

$$\Delta\pi = +50''.25, \quad \Delta\Omega = +42''.30, \quad \Delta i = +0''.23$$

The equations of the coordinates for the respective years are:

$$1886.0 \left\{\begin{aligned} x &= [n9.9996185]\ (v+97°\ 30'\ 42''.5) \\ y &= [n9.9562858]\ (v+\ 8\ \ 38\ \ 47\ .1) \\ z &= [n9.6325231]\ (v+\ 2\ \ 26\ \ 50\ .9) \end{aligned}\right.$$

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The normal places are thus represented:

	C—O Δλ	C—O Δβ
Sept. 30.5	0″.0	0″.0
Oct. 23.0	+0 .6	[−2 .9]
Nov. 19.5	+0 .9	[−3 .4]
Dec. 19.0	0 .0	0 .0

In order to investigate more fully the character of the discrepancies between calculation and observation, I have prepared the subjoined table, including in it nearly all the observations made at the Dudley Observatory, with such others as could conveniently be included without calculation of additional ephemeris-dates.

	Place	Δα	Δδ
September 29	*Rome	+0.29	+ 7.1
	*Nice	−0.57	+ 1.3
	*Lyons	−0.20	− 3.1
	*Albany	−0.48	− 1.9
	*Nashville	+0.69	− 6.1
September 30	*Vienna	+0.91	+ 3.9
	*Lyons	+0.71	+ 0.4
	*Washington	−0.04	− 1.5
October 1	*Vienna	−0.24	−14.1
	*Rome	+0.14	−10.8

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		Place	$\Delta\alpha$	$\Delta\delta$
			s	''
October	1	*Nice	−0.09	+ 5.0
		*Washington	−0.05	+11.5
October	22	Turin	−1.15	− 7.9
		*Rome (2)	−0.11	− 9.7
		*Washington	+0.04	− 1.9
		*Albany	+0.24	− 0.6
October	23	Kremsmünster (2)	−1.36	−15.2
		*Rome (2)	−0.18	− 6.1
		*Albany	+0.15	+ 1.7
		*Washington	+0.03	− 4.5
October	28	Kremsmünster	−0.77	−11.8
		"	−1.10	−15.8
October	29	Kremsmünster	−0.62	+ 3.6
		"	−0.33	− 1.2
October	30	Kremsmünster	−0.93	+ 5.0
		"	−0.58	+ 8.3
October	31	Kremsmünster	−1.21	+ 3.0
November	1	Kremsmünster	−0.36	+ 2.1
		Rome	−0.58	−13.4
		Albany	+0.06	− 2.5
November	2	Albany	+0.21	− 0.7
November	5	Albany	+0.35	+ 0.1
November	7	Rome	−0.34	− 3.3
		"	−0.63	− 5.8
November	16	Kremsmünster	−0.53	+ 0.7
		Rome	−0.14	− 4.7
		*Albany	−0.05	− 2.4
		* "	−0.61	− 1.3
November	18	*Albany	+0.26	− 7.9
		Washington	+0.25	+ 5.8
November	19	Washington	+0.17	−12.7
		*Albany	+0.04	− 2.2
		* "	−0.38	− 4.3
November	20	Rome	−0.32	− 9.3
November	21	*Albany	+0.30	− 2.4
		* "	+0.48	+ 3.1
December	6	Albany	+0.26	+ 3.7
December	16	*Albany	−0.37	+ 1.7
		* "	−0.04	− 0.1
December	17	*Albany	−0.36	+ 1.7
		* "	+0.13	− 1.0
		* "	0.00	+ 1.3
		* "	+0.08	− 0.8
December	20	*Albany	+0.32	+ 3.1
December	21	*Albany	+0.19	− 0.8
December	27	Albany	−0.48	− 2.7

In the case of several observations, embraced in the foregoing table, the comparison-star is not well determined, or the number of comparisons is only one or very few. From October 22 to November 20, inclusive, the prevalence of the negative sign in the residuals for declination is apparent. Between those dates, from $+2''$ to $+3''$ should be added to the ephemeris-declinations in order to get the best representation of observations. The trouble has probably arisen from systematic errors in the normal right-ascensions used in the calculation, and from weakness in the declination of the first normal place. At all events the errors are mostly small, and they indicate that the elements concerned must be very near the truth, and that the consequent periodic time is no more than a few days in error. Of these differences the most important come from the Kremsmünster series, which appear to differ systematically from the consensus of other observations during the same period by something like $0^s.8$ in right-ascension. The observations are made with the use of a ring-micrometer, and the differences of declination appear to be a function of the differences, ☄ − ✱, in the comparisons. They are fairly well represented by the formula: $+1''.1 - 1''.4$ (☄ − ✱) where the difference (☄ − ✱) is expressed in minutes. In the Albany observations with filar micrometer, the attention of the observer was in each case directed to the avoidance of a habit of observing favorable to the existence of large constant errors. Of course, it is impossible for any observer by a mere effort of the will altogether to avoid such errors, which in the nature of the case are, to a certain extent, unavoidable. I have, however, frequently noticed a tendency on my own part, when observing transits of the comet over the illuminated micrometer-wires, to wait too long for the reappearance of the image. This tendency I have tried to conquer by experiment with the phases of transit, previous to observation, in order to facilitate judgement as to when the central condensation is really under the wire. It is also possible that changes in the form of the comet, while in the vicinity of perihelion, may have materially altered the relation of apparent center of brightness to the center of gravity. The comet has always appeared to me to be without nucleus proper, and with a central condensation of light (observable with illuminated wires) of from $6''$ to $10''$ in diameter.

The elements already presented render the question of identity with DeVico's comet rather problematical, to say the least. In favor of such identity is the near coincidence of the planes of revolution. Further it is hardly credible that, with unchanged elements, DeVico's comet should have escaped observation since Goldschmidt's single rough observation in 1855, if indeed that were really an observation of the comet in question. Judging from appearances, the two bodies must be of nearly the same intrinsic brightness. At the last reported observation of DeVico's comet, by Otto Struve at Pulkowa (1844 December 31,) the theoretical brightness of that object was about 0.5 on the scale of light adopted in the ephemeris at the end of this article; being nearly equal to that which the present comet will have on February 16, and one-half that which it had at discovery in September last. Against these considerations are the important differences in the elements, such as $24^\circ.5$ between the lines of apsides; nearly 12° between the lines of nodes; 0.44 in the length of the semi-axes; and $6^\circ.8$ in the angles of eccentricity. Yet, even in these elements there is not

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sufficient discrepancy to remove the suspicion of possible identity. The greatest apparent objection lies in the swinging of the line of apsides combined with the relatively great difference in perihelion-distance through the combined differences of the semi-axis and angle of eccentricity. But if we choose to examine the hypothesis of identity, it must be shown that perturbing forces may have acted with sufficient power to produce these great changes; and in looking for the source of such forces we are confronted with important difficulties. Unless the elements of each of these comets are supposed to be very different from those given by calculation, neither of the comets could have experienced any extraordinary perturbations by *Jupiter* in the interval from 1844 to 1886. In 1873–4 when DeVico's comet was, by the undisturbed elements, in aphelion, its least distance from *Jupiter* was about twice the terrestrial radius, and while this would have led to important perturbations, the possible disturbance is not equal to that required by the hypothesis of identity with the comet of Finlay, without supposing a shortening of the period of DeVico's comet, much greater than seems to be readily admissible. Furthermore if one supposes such shortening of the period to be probable, and that great perturbations by *Jupiter* were produced, it will be quite as difficult to show how, under the theory of identity, DeVico's comet could have made its appearance at the present time. According to the present calculation the Finlay comet should have been (by the undisturbed elements) at aphelion in March, 1870, and again near the end of 1876. Working back, it appears that the comet of Finlay has at no time, in the last 30 years at least, attained a Jovicentric distance of less than 3.0, except for the changes produced by perturbations.

The suggestion of mine, in No. 145 of this Journal, that the source of the disturbance might possibly be found among the small planets, is negatived by the relations of the two orbits in space.

There is however an interesting conjunction of the respective trajectories of the two comets with that of *Mars* in the interval of heliocentric longitude 287°–296°. Here the tangents of the orbits make small angles with their mean direction. The possible least Areocentric distance of the DeVico comet is at about 288° of longitude, and is only 0.011. The Finlay comet's trajectory does not approach that of *Mars* quite so closely, but can be as small as 0.025 in longitude 295°. Another close approach to *Mars* is possible for the DeVico comet, at heliocentric longitude 42°, and for the Finlay comet in 90°; but it is probably in the vicinity of longitude 290° that we must look for the great perturbations by *Mars*, if they have been exerted at all.

I have examined with some care the dates when it is reasonable to suppose that each of the comets in turn may have been in the vicinity of this point with the planet; but there is only one occasion when the comets may have been supposed to be — both of them — near this point at the same time. This occurs in 1866, and Mars was also at the point nearest the trajectory of DeVico's comet, 1866 February 24. This is certainly an interesting coincidence, even though on that date, by the undisturbed elements, DeVico's comet was past the point in question about 80 days, and Finlay's comet, 180 days. The theoretical meeting of the *radii vectores* of the two comets is, by calculation, in January, 1865; but at the time above mentioned the present comet was only 100 days in advance of DeVico's comet. In order to bring them together with the same heliocentric longitude (equal also to that of *Mars* at the time) it is necessary to suppose that the period of DeVico's comet proved to be only 20 days shorter than the one found by BRÜNNOW; but it is also necessary to suppose that the average period of the Finlay comet since 1866 has been greater by 60 days than that which has been found in this article. It will hardly be admitted that the period, as now found, is subject to a correction of half that amount at the present time; and it remains to be seen whether perturbations by *Mars*, *Jupiter* and *Saturn* would be sufficient to account for the difference. My impression, from a superficial inspection of the problem, is that the perturbations by *Jupiter* in the period 1875–7 would have a tendency to shorten the period which the Finlay comet may have had at that time. The solution of that question is only possible, however, through a rigorous analysis — based upon the best attainable treatment of observations at the present appearance, and supplemented, if the state of the case appears to demand it, by a rediscussion of the comet of 1844. Should the hypothesis of identity be sustained it is evident that fresh interest would attach to the questions of identity with comets of the past, and especially with the comets of 1585 and 1678.

Working backward toward 1844 with the undisturbed elements of the Finlay comet, perihelia result at these dates: 1880 March 20; 1873 July 17; and 1866 November 13. Of these, the first is entirely unfavorable for observation; the second is less favorable than the present, with the comet visible only in the early morning hours; and the third (in 1866), is slightly more favorable than the present, resembling it in general relations. But the supposition of an average increase in the period of 60 days makes the dates as follows: 1880, January; 1873, March; and 1866, May. All of these would be unfavorable to the chance of detection, even by the keenest sighted and most industrious of comet-hunters. This is negative evidence only, yet it must have, though slight, still a favorable bearing upon the hypothesis of identity.

With undisturbed elements the next perihelion of the Finlay comet would occur July 26, 1893, subject to the error in the periodic time. The following little ephemeris shows that the conditions for observation would be somewhat inferior to those of the present appearance.

Date	α	δ	r	Δ
1893 May 6	$21^h\ 58^m$	$-15°$	1.50	1.38
June 15	1 0	+ 4	1.11	1.01
July 26	4 20	+ 22	1.00	1.07

Elongation from the sun, at the last date, is less than 58°. The conditions for observation would be improved by any

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lengthening of the period under 100 days, and as the track of the comet is quite clear of the large planets for the next 7 years, we may count with some confidence upon observing it at its next return.

Date, 1887	App. α	Hourly Motion	App. δ	Hourly Motion	log r	log Δ	Light
	h m s	s	° ′ ″	″			
January 6	0 17 55.93	+11.916	+ 2 28 34.5	+87.65	0.074615	9.947600	2.0
7	22 40.98	11.838	3 3 27.7	86.75			
8	27 24.12	11.757	3 37 58.4	85.79			
9	32 5.31	11.675	4 12 5.4	84.76			
10	36 44.51	11.592	4 45 47.1	83.69	0.085593	9.960503	1.8
January 11	0 41 21.71	11.508	5 19 2.5	82.57			
12	45 56.87	11.422	5 51 50.4	81.40			
13	50 29.96	11 335	6 24 9.9	80.20			
14	55 0.97	11.249	6 56 0.1	78.97	0.096754	9.975120	1.6
15	0 59 29.89	11.161	7 27 20.4	77.70			
January 16	1 3 56.70	11.073	7 58 9.9	76.41			
17	8 21.39	10.984	8 28 28.1	75.10			
18	12 43.95	10.896	8 58 14.6	73.77	0.108018	9.991191	1.4
19	17 4.38	10.807	9 27 28.9	72.42			
20	21 22.68	10.718	9 56 10.6	71.06			
January 21	1 25 38.85	10.629	10 24 19.6	69.69			
22	29 52.89	10.541	10 51 55.6	68.31	0.119318	0.008443	1.2
23	34 4.79	10.451	11 18 58.4	66.93			
24	38 14.56	10.362	11 45 28.1	65.54			
25	42 22.19	10.274	12 11 24.5	64.16			
January 26	1 46 27.71	10.186	12 36 47.8	62.78	0.130598	0.026611	1.1
27	50 31.11	10.098	13 1 38.0	61.41			
28	54 32.40	10.011	13 25 55.3	60.04			
29	1 58 31.63	9.923	13 49 39.9	58.68			
30	2 2 28.71	9.836	14 12 52.0	57.33	0.141812	0.045450	0.9
January 31	2 6 23.75	9.751	14 35 31.8	56.00			
February 1	10 16.74	9.666	14 57 39.8	54.67			
2	14 7.70	9.581	15 19 16.0	53.36			
3	17 56.61	9.496	15 40 21.0	52.07	0.152922	0.064745	0.8
4	21 43.51	9.413	16 0 55.2	50.79			
February 5	2 25 28.43	9.330	16 20 58.8	49.52			
6	29 11.37	9.249	16 40 32.4	48.28			
7	32 52.37	9.168	16 59 36.3	47.06	0.163899	0.084316	0.7
8	36 31.44	9.088	17 18 11.1	45.85			
9	40 8.60	9.009	17 36 17.0	44.66			
February 10	2 43 43.88	8.932	17 53 54.8	43.49			
11	47 17.32	8.855	18 11 4.7	42.34	0.174719	0.104012	0.6
12	50 48.94	8.780	18 27 47.3	41.22			
13	54 18.76	8.706	18 44 3.2	40.11			
14	2 57 46.81	8.633	18 59 52.8	39.03			
February 15	3 1 13.13	8.561	19 15 16.6	37.97	0.185365	0.123707	0.5
16	4 37.74	8.491	19 30 15.2	36.92			
17	8 0.67	8 421	19 44 49.0	35.90			
18	11 21.95	8.353	19 58 58.5	34.90			
19	14 41.60	8.285	20 12 44.3	33.92	0.195822	0.143294	0.5
February 20	3 17 59.65	8.219	20 26 6.8	32.96			
21	21 16.12	8.154	20 39 6.5	32.02			
22	24 31.04	8.090	20 51 43.9	31.10			
23	27 44.43	8.026	21 3 59.3	30.20	0.206081	0.162680	0.4
24	30 56.31	7.964	21 15 53.2	29.31			

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Date, 1887	App. α	Hourly Motion	App. δ	Hourly Motion	log r	log Δ	Light
	h m s	s	° ′ ″	′			
February 25	3 52 39.23	7.903	21 27 26.1	28.44			
26	3 34 6.71	7.842	21 38 38.4	27.59			
27	37 15.65	7.783	21 49 30.6	26.76	0.216137	0.181794	0.4
28	40 23.15	7.725	22 0 3.0	25.95			
March 1	43 29.24	7.667	22 10 16.1	25.15			
	46 33.94						
March 2		7.610	22 20 10.4	24.37			
3	3 49 37.26	7.554	22 29 46.1	23.61	0.225984	0.900574	0.3

Dudley Observatory,
Albany, N.Y., 1887 *January* 8.

ON THE NEW *ALGOL*-VARIABLE IN *CYGNUS*. 7488

$20^h\ 46^m\ 16^s.1$; $+34°\ 6'\ 57''$ (1855.0).

BY S. C. CHANDLER, JR.

Since the appearance of No. 149 no opportunity has been lost to get additional observations of this star, but although two minima were secured on January 2 and 11, no means of discriminating among the hypotheses as to the period occurred, until observations obtained in the strong morning twilight, January $12^d\ 17^h\ 15^m$ to $18^h\ 5^m$, showed the star in its normal maximum brilliancy, apparently. By the very rude elements already given, a minimum would have occurred January $12^d\ 17^h\ 50^m$ if the period were $1^d.4992$ or $0^d.7496$. From that it would appear that the hypothesis $n = 2$ is the correct one, but further watch is desirable for a conclusive decision. Neither is it entirely certain that any part of the real decrease has yet been seen. The apparent decrease, in the table of observations below, on December 27, January 2 and January 11, may be the effect of rapidly diminishing twilight on the relative aspect of the variable and its comparison-stars; so that the true epoch of minimum is yet to be found.

Some detail as to the circumstances attending the discovery and observations, omitted from No. 149 for want of space, may be of service in affording hints for following up other suspicious cases of this kind. I have long deemed it probable that the comparative fewness of the *Algol*-type variables is due not to their actual rarity, but to the difficulties attending their discovery. The way in which they are likely to present themselves to the observer is so elusive, that he is apt to misjudge the single discordant observation among many accordant ones, and treat it as erroneous, instead of examining the case further and tracing the exceptional record to its true origin.

On one or two evenings previous to December 9, I had noticed that this star seemed out of its usual relation in brightness to others in the region. On that date the difference was more marked; the star being scarcely visible in the bright moonlight with the field-glass, while its neighbors, ordinarily equal to it, were conspicuous. About two hours later the observation was repeated, with a larger telescope, on account of increasing haze and moonlight, but the stars appeared in their usual relation. Making all allowances for difference of the extraneous circumstances, I was at the time puzzled by these observations, although it is now plain that in the short interval between them the star had regained its usual brilliancy. A nightly watch was kept without result until December 21, when the star was again caught below its usual magnitude. Comparisons during the evening, although made under embarrassing circumstances during a railroad journey, showed a distinct increase and enabled me to recognize the peculiar character of the variable. Since that time it has been examined, every half-hour or oftener, on every possible occasion, including hopeless searches in the morning twilight. Three additional minima have been thus secured, as noticed above, which include apparently a small portion of the decrease and the whole of the increase.

The comparison-stars, with their magnitudes according to the DM., and also those which I assign on the same scale, together with my provisional light-scale, are as follows:

	1855.0		Magnitude.		L
	h m s	° ′	D.M.	Ch.	
k	20 51 26	+34 45.2	6.5	7.00	13.5
l	49 6	33 12.4	7.3	7.05	13
e	43 30	35 1.7	7.5	7.15	12
m	52 51	34 10.4	7.6	7.60	8
n	49 51	33 28.4	7.5	7.80	6
p	47 16	34 12.3	7.8	7.90	5
var.	46 16	34 6.9	7.5	7.1–7.9	

The light of the variable ranges from 11.5 or 12 at maximum, to 5.0 or less at minimum; or, expressed in magnitude, from $7^M.1$ to $7^M.9$. The inferior limit is as yet uncertainly determined.

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The following table gives the light of the variable at each observation. The letter *n* signifies that the star was recorded as at its normal or maximum brightness, which is about 11.5 or 12.0 of the light-scale. The letter *a* signifies that the observations were made with a Clacey 6¼ inch; *b*, that they were continued, as the twilight deepened, with this telescope and also with the 2-inch finder and the field-glass; and *c*, that only the last two instruments were used. No letter is affixed to observations with the field-glass alone.

Observations.

Camb. M.T.				*L*	
1886	d	h	m		
Dec.	9	6	15	7.0	
	10	8	51	*n*	
	11	5	45	*n*	
	14	5	45	*n*	
	16	7	3	*n*	
	17	6	15	*n*	
	19	6	27	*n*	
	20	7	51	14.0:	
	21	5	45	8.7	
	21	7	15	8.7	
	21	9	21	10.5	
	22	6	15	13.0:	
	25	5	45	11.3	
	25	6	27	11.7	
	25	9	15	11.7	
	27	5	45	7.2	
		5	59	6.7	
		6	10	6.6	
		6	15	7.8	
		6	33	8.0	
		7	15	8.5	
		7	43	9.3	
		8	1	10.0	
		8	25	10.0	
		9	3	10.9	
		9	30	11.1	
	28	5	35	11.0:	
		5	45	12.2	
		6	35	12.2	
		7	5	12.2	
		7	45	12.2	
		8	20	11.4	
		8	37	11.2	
		8	48	11.2	
1886					
Dec.	28	8	59	11.2	
		9	15	11.2	
1887		9	35	11.2	
Jan.	2	5	7	8.0	*a*
		5	10	6.0	*a*
		5	15	5.5	*a*
		5	18	5.3	*a*
		5	21	5.0	*a*
		5	23	4.8	*a*
		5	28	5.0	*a*
		5	38	6.2	*a*
		5	45	7.0	*a*
		5	52	6.7	*b*
		5	59	7.5	*b*
		6	6	8.0	*b*
		6	28	8.2	*c*
		6	52	8.9	*c*
		7	29	9.8	*c*
		8	4	10.6	*c*
		8	42	11.0	*c*
	3	6	5	11.8	
	4	6	25	10.8	
	6	18	15	<*p*	
	10	5	57	*n*	*a*
		6	35	*n*	*a*
		7	47	*n*	*a*
		8	4	*n*	*a*
		8	55	11.4	*a*
		9	15	10.3	*a*
		9	35	10.3:	*a*
	11	5	17	4.7	*a*
		5	27	4.3	*a*
		5	30	4.3	*a*
		5	33	3.7	*a*
1887					
Jan.	11	5	37	4.5	*a*
		5	41	4.8	*a*
		5	44	5.7	*a*
		5	57	5.7	*a*
		6	10	7.0	*a*
	12	6	10	*n*	*c*
1887					
Jan.	12	17	15	*n*	*a*
		17	25	*n*	*a*
		17	35	*n*	*a*
		17	45	*n*	*a*
		18	5	*n*	*a*

From these observations are derived the following times of minima:

E	Observed Camb. M.T.					Light Equation	Heliocentric Camb. M.T.				Wt.	O—C
			d	h	m	m		d	h	m		
0	1886 Dec.		9	6	15	—2.1	Dec.	9	6	17	½	—10
4			21	6	12	—3.0		21	6	15	1	+ 4
6			27	6	0	—3.4		27	6	3	1	0
8	1887 Jan.		2	5	54	—3.8	Jan.	2	5	58	1	+ 3
11			11	5	34	—4.4		11	5	58	1	— 5

The comparison in the last column is with the elements

$$1886 \text{ Dec. } 9^d\, 6^h\, 22^m \text{ Camb. M.T.} + [2^d\, 23^h\, 56^m.0]\, E.$$

These elements give the ephemeris for Washington M.T.

E	1887 Wash. M.T.	d	h	m	E	1887 Wash. M.T.	d	h	m
13	Jan.	17	5	11	22	Feb.	13	4	35
14		20	5	7	23		16	4	31
15		23	5	3	24		19	4	27
16		26	4	59	25		22	4	23
17		29	4	55	26		25	4	19
18	Feb.	1	4	51	27		28	4	15
19		4	4	47	28	Mar.	3	4	11
20		7	4	43	29		6	4	7
21		10	4	39	30		9	4	3

It is a curious and unfortunate circumstance that the near commensurability of the period with the mean solar day, will prevent further observation in the eastern portion of the United States for a period of about twenty months—unless one or two additional minima are immediately obtained with telescopes of considerable size, in the bright evening twilight—and also on the Pacific coast until January of next year. Observations are still possible for a very short period in middle Europe. In northern Europe the star is near the circle of perpetual apparition, but even there the minima are invisible for long series of months together, on account of daylight.

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OBSERVATIONS OF VARIABLE STARS IN 1885.

By EDWIN F. SAWYER.

The following observations of variable stars were made during the year 1885 at Cambridgeport, Mass. The same methods of observation and reduction were employed as during former years (*Astr. Nachr.* no. 2660).

Owing to a severe illness, the observations were much interrupted during the months of July, August and September, but fortunately the breaks in the series were not of such a serious character that the times of maxima and minima (with a few exceptions) could not be determined with the usual precision. Over 1500 observations of 50 stars were obtained during the year; but the reduction of the observations of many of these stars has been delayed for want of time and will be given as occasion offers in separate communications.

1. *R Andromedae.*

This star was observed from December 5, 1884, to March 17, 1885, 39 observations being obtained. When first seen on December 5 R was 3 steps > DM. 37°,57, and 4 or 5 steps < DM. 38°,46, or $8^{\rm M}.8$. The increase of light was rapid, and a maximum was passed January 10. Maximum brightness, 5 steps > DM. 37°,54, and = DM. 36°,12, or $6^{\rm M}.6$; this being slightly brighter than the maximum of last year. Its light remained apparently constant for the 31 days from December 29 to January 29. The decrease of light was very slow, and when last observed, March 17, R was 3 steps > DM. 37°,75, 2 or 3 steps < DM. 36°,39, and 5 steps < DM. 37°,42, or $7^{\rm M}.3$.

2. *R Leonis.*

Observations were begun on this star November 14, 1884, and terminated on June 17, 1885, owing to the star's near approach to the sunset horizon, 47 observations being obtained. When first seen, on November 14, R was 4 or 5 steps > DM. 11°,2108, and 3 steps < DM. 12°,2105, or $7^{\rm M}.2$. The increase of light was regular, but not very rapid. A maximum was passed about December 24, 1884. Maximum brightness = DM. 9°,2188, or $5^{\rm M}.3$; this being nearly $1\frac{1}{2}$ magnitudes brighter than the maximum of last year. The series was much broken near the maximum by cloudy weather and moonlight. The decrease of light was slow and regular, and when last observed, on June 17, R was 4 steps < DM. 12°,2094, or $9^{\rm M}.9$. R was evidently near minimum when the observations ended; the light remaining constant from June 1 to 17. From May 9 the observations were made with the refractor.

3. *R Leonis Minoris.*

Observed from May 10 to July 15, 24 observations being obtained. When first observed, May 10, R was 5+ steps < DM. 35°,2054, or about $9^{\rm M}.5$. The increase of light was rapid, and a maximum was reached on June 26. Maximum brightness 5 steps > DM. 33°,1907, 3 or 4 steps > DM. 34°,2022, and 1 or 2 steps < DM. 34°,2035, or $6^{\rm M}.8$; this being about half a magnitude brighter than the maximum last year. When last observed, on July 15, R was 4 steps > D.M. 33°,1907, 1 or 2 steps < D.M. 34°,2022, and 4 or 5 steps < DM. 34°,2035, or $7^{\rm M}.1$.

4. *R Bootis.*

This star was observed from April 6 till July 10; 29 observations. When first seen, April 6, R was 5 steps < DM. 27°,2403, or about $9^{\rm M}.0$. The increase of light was rapid until April 16. From April 16 to 30 the increase was very slow, but from April 30 to May 9 it was again rapid. The maximum occurred on May 16. Maximum brightness = 3 steps > DM. 26°,2592 and = DM. 29°,2555, i.e., $7^{\rm M}.8$, or nearly half a magnitude fainter than the observed maximum last year. The decrease of light appeared rather rapid and uniform, and when last observed, on July 10, R was 5+ steps < DM. 27°,2403, or about $9^{\rm M}.0$.

5. *R Draconis.*

Observed from April 6 to June 14, 27 observations, and from December 2 to February 5, 1886, 22 observations. When first observed, April 6, R was 5 steps < DM. 67°,943, or about $9^{\rm M}.7$. The increase of light was rapid and uniform. The first maximum was reached on May 7; the maximum brightness being 2 steps > DM. 67°,962, and 2 steps < DM. 68°,883, or $7^{\rm M}.8$; or nearly half a magnitude fainter than the maximum observed last year. The decrease of light was rather slow, and when last observed, June 14, R was 2 or 3 steps > DM. 67°,943, and 4 steps < DM. 67°,945, or $8^{\rm M}.9$.

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The following table gives the light of the variable at each observation. The letter *n* signifies that the star was recorded as at its normal or maximum brightness, which is about 11.5 or 12.0 of the light-scale. The letter *a* signifies that the observations were made with a Clacey $6\frac{1}{4}$ inch; *b*, that they were continued, as the twilight deepened, with this telescope and also with the 2-inch finder and the field-glass; and *c*, that only the last two instruments were used. No letter is affixed to observations with the field-glass alone.

OBSERVATIONS.

Camb. M.T. d h m	L	Camb. M.T. d h m	L
1886 Dec. 9 6 15	7.0	1886 Dec. 28 8 59	11.2
10 8 51	*n*	9 15	11.2
11 5 45	*n*	9 35	11.2
14 5 45	*n*	1887 Jan. 2 5 7	8.0 *a*
16 7 3	*n*	5 10	6.0 *a*
17 6 15	*n*	5 15	5.5 *a*
19 6 27	*n*	5 18	5.3 *a*
20 7 51	14.0:	5 21	5.0 *a*
21 5 45	8.7	5 23	4.8 *a*
21 7 15	8.7	5 28	5.0 *a*
21 9 21	10.5	5 38	6.2 *a*
22 6 15	13.0:	5 45	7.0 *a*
25 5 45	11.3	5 52	6.7 *b*
25 6 27	11.7	5 59	7.5 *b*
25 9 15	11.7	6 6	8.0 *b*
27 5 45	7.2	6 28	8.2 *c*
5 59	6.7	6 52	8.9 *c*
6 10	6.6	7 29	9.8 *c*
6 15	7.8	8 4	10.6 *c*
6 33	8.0	8 42	11.0 *c*
7 15	8.5	3 6 5	11.8
7 43	9.3	4 6 25	10.8
8 1	10.0	6 18 15	$\nless p$
8 25	10.0	10 5 57	*n* *a*
9 3	10.9	6 35	*n* *a*
9 30	11.1	7 47	*n* *a*
28 5 35	11.0:	8 4	*n* *a*
5 45	12.2	8 55	11.4 *a*
6 35	12.2	9 15	10.3 *a*
7 5	12.2	9 35	10.3: *a*
7 45	12.2	11 5 17	4.7 *a*
8 20	11.4	5 27	4.3 *a*
8 37	11.2	5 30	4.3 *a*
8 48	11.2	5 33	3.7 *a*

Camb. M.T. d h m	L	Camb. M.T. d h m	L
1887 Jan. 11 5 37	4.5 *a*	1887 Jan. 12 17 15	*n* *a*
5 41	4.8 *a*	17 25	*n* *a*
5 44	5.7 *a*	17 35	*n* *a*
5 57	5.7 *a*	17 45	*n* *a*
6 10	7.0 *a*	18 5	*n* *a*
12 6 10	*n* *c*		

From these observations are derived the following times of minima:

E	Observed Camb. M.T. d h m	Light Equation m	Heliocentric Camb. M.T. d h m	Wt.	O—C
0	1886 Dec. 9 6 15	—2.1	Dec. 9 6 17	½	—10
4	21 6 12	—3.0	21 6 15	1	+ 4
6	27 6 0	—3.4	27 6 3	1	0
8	1887 Jan. 2 5 54	—3.8	Jan. 2 5 58	1	+ 3
11	11 5 34	—4.4	11 5 58	1	— 5

The comparison in the last column is with the elements

$$1886 \text{ Dec. } 9^d\ 6^h\ 22^m \text{ Camb. M.T.} + [2^d\ 23^h\ 56^m.0]\,E$$

These elements give the ephemeris for Washington M.T.

E	1887 Wash. M.T. d h m	E	1887 Wash. M.T. d h m
13	Jan. 17 5 11	22	Feb. 13 4 35
14	20 5 7	23	16 4 31
15	23 5 3	24	19 4 27
16	26 4 59	25	22 4 23
17	29 4 55	26	25 4 19
18	Feb. 1 4 51	27	28 4 15
19	4 4 47	28	Mar. 3 4 11
20	7 4 43	29	6 4 7
21	10 4 39	30	9 4 3

It is a curious and unfortunate circumstance that the near commensurability of the period with the mean solar day, will prevent further observation in the eastern portion of the United States for a period of about twenty months—unless one or two additional minima are immediately obtained with telescopes of considerable size, in the bright evening twilight —and also on the Pacific coast until January of next year. Observations are still possible for a very short period in middle Europe. In northern Europe the star is near the circle of perpetual apparition, but even there the minima are invisible for long series of months together, on account of daylight.

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OBSERVATIONS OF VARIABLE STARS IN 1885.

BY EDWIN F. SAWYER.

The following observations of variable stars were made during the year 1885 at Cambridgeport, Mass. The same methods of observation and reduction were employed as during former years (*Astr. Nachr.* no. 2660).

Owing to a severe illness, the observations were much interrupted during the months of July, August and September, but fortunately the breaks in the series were not of such a serious character that the times of maxima and minima (with a few exceptions) could not be determined with the usual precision. Over 1500 observations of 50 stars were obtained during the year; but the reduction of the observations of many of these stars has been delayed for want of time and will be given as occasion offers in separate communications.

1. *R Andromedae.*

This star was observed from December 5, 1884, to March 17, 1885, 39 observations being obtained. When first seen on December 5 *R* was 3 steps $>$ DM. 37°,57, and 4 or 5 steps $<$ DM. 38°,46, or 8^{M}.8. The increase of light was rapid, and a maximum was passed January 10. Maximum brightness, 5 steps $>$ DM. 37°,54, and $=$ DM. 36°,12, or 6^{M}.6; this being slightly brighter than the maximum of last year. Its light remained apparently constant for the 31 days from December 29 to January 29. The decrease of light was very slow, and when last observed, March 17, *R* was 3 steps $>$ DM. 37°,75, 2 or 3 steps $<$ DM. 36°,39, and 5 steps $<$ DM. 37°,42, or 7^{M}.3.

2. *R Leonis.*

Observations were begun on this star November 14, 1884, and terminated on June 17, 1885, owing to the star's near approach to the sunset horizon, 47 observations being obtained. When first seen, on November 14, *R* was 4 or 5 steps $>$ DM. 11°,2108, and 3 steps $<$ DM. 12°,2105, or 7^{M}.2. The increase of light was regular, but not very rapid. A maximum was passed about December 24, 1884. Maximum brightness $=$ DM. 9°,2188, or 5^{M}.3; this being nearly $1\frac{1}{2}$ magnitudes brighter than the maximum of last year. The series was much broken near the maximum by cloudy weather and moonlight. The decrease of light was slow and regular, and when last observed, on June 17, *R* was 4 steps $<$ DM. 12°,2094, or 9^{M}.9. *R* was evidently near minimum when the observations ended; the light remaining constant from June 1 to 17. From May 9 the observations were made with the refractor.

3. *R Leonis Minoris.*

Observed from May 10 to July 15, 24 observations being obtained. When first observed, May 10, *R* was 5+ steps $<$ DM. 35°,2054, or about 9^{M}.5. The increase of light was rapid, and a maximum was reached on June 26. Maximum brightness 5 steps $>$ DM. 33°,1907, 3 or 4 steps $>$ DM. 34°,2022, and 1 or 2 steps $<$ DM. 34°,2035, or 6^{M}.8; this being about half a magnitude brighter than the maximum last year. When last observed, on July 15, *R* was 4 steps $>$ D.M. 33°,1907, 1 or 2 steps $<$ D.M. 34°,2022, and 4 or 5 steps $<$ DM. 34°,2035, or 7^{M}.1.

4. *R Bootis.*

This star was observed from April 6 till July 10; 29 observations. When first seen, April 6, *R* was 5 steps $<$ DM. 27°,2403, or about 9^{M}.0. The increase of light was rapid until April 16. From April 16 to 30 the increase was very slow, but from April 30 to May 9 it was again rapid. The maximum occurred on May 16. Maximum brightness $=$ 3 steps $>$ DM. 26°,2592 and $=$ DM. 29°,2555, i.e., 7^{M}.8, or nearly half a magnitude fainter than the observed maximum last year. The decrease of light appeared rather rapid and uniform, and when last observed, on July 10, *R* was 5+ steps $<$ DM. 27°,2403, or about 9^{M}.0.

5. *R Draconis.*

Observed from April 6 to June 14, 27 observations, and from December 2 to February 5, 1886, 22 observations. When first observed, April 6, *R* was 5 steps $<$ DM. 67°,943, or about 9^{M}.7. The increase of light was rapid and uniform. The first maximum was reached on May 7; the maximum brightness being 2 steps $>$ DM. 67°,962, and 2 steps $<$ DM. 68°,883, or 7^{M}.8; or nearly half a magnitude fainter than the maximum observed last year. The decrease of light was rather slow, and when last observed, June 14, *R* was 2 or 3 steps $>$ DM. 67°,943, and 4 steps $<$ DM. 67°,945, or 8^{M}.9.

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The second maximum, which was a remarkably bright one, was passed 1886 January 2. Maximum brightness 3 or 4 steps > DM. 69°,942, =DM.68°,868, and 4 steps < DM. 67°,930, or $6^{M}.5$. The interval between the first and second maximum =240 days.

6. *R Virginis.*

The observations of this star extended from May 2 to July 15, and are 31 in number. *R* was 5 steps < DM. 7°,2562, or about $9^{M}.8$, when first seen on May 2. The increase of light was at first rather slow; but afterwards became quite rapid. A maximum was passed on June 13. Maximum brightness was 3 or 4 steps > DM. 8°,2619, and 3 or 4 steps < DM. 9°,2648, or $7^{M}.0$, being of about the same brightness as last year. When last observed, July 15, *R* was 5 steps < DM. 8°,2617, or $7^{M}.6$.

7. *U Virginis.*

Only five observations of this star were obtained, the series extending from March 17 to April 6. The observations were begun too late to obtain a good determination of the maximum, which apparently occurred about the time they commenced. Brightness = 1 or 2 steps > DM. 6°,2673, and 2 steps < DM. 7°,2588, or $8^{M}.1$.

8. *R Ursae Majoris.*

32 observations were obtained on this star, extending from June 1 to September 2. When first observed, on June 1, *R* was 5+ steps < DM. 70°,624, or about $9^{M}.3$. The increase of light was very rapid and uniform, and a maximum was passed on July 1. Maximum brightness, 3 steps > DM. 69°,577, and 1 or 2 steps < DM. 69°569, or $7^{M}.5$. The decrease of light also appeared quite rapid, and when last observed, on September 2, *R* was 5 steps < DM. 70°624, or about $9^{M}.3$.

9. *S Ursae Majoris.*

This star was observed on 32 evenings, from April 6 to June 14. When first seen, on April 6, *S* was 5 steps > DM. 61°,1310, and 4 or 5 steps < DM. 60°,1416, or $8^{M}.3$. The increase of light was rather slow, and a maximum was passed on May 7. Maximum brightness, 4 steps > DM. 60°,1416, and 2 steps < DM. +62°,1257, or $7^{M}.7$. The decrease of light appeared somewhat rapid, and when last observed, June 14, *S* was =DM. 61°,1311, and 5 steps < DM. 61°,1310, or $9^{M}.1$.

10. *T Ursae Majoris.*

Observed from May 9 to August 15, 34 observations being obtained. On the date of the first observation, May 9, *T* was 5+ steps < DM. 60°,1408, or about $9^{M}.0$. The increase of light was rapid, and a maximum was passed on June 22. Maximum brightness = DM. 60°,1413, and 4 or 5 steps < DM. 60°,1416, or $8^{M}.5$, this representing a faint maximum. The light remained apparently constant from June 6 to July 8, or 33 days. The decrease of light after July 16 was rather rapid, and when last observed, on August 15, *T* was 2 or 3 steps > DM. 60°,1408, and 5 steps < DM. 61°,1311, or $8^{M}.7$.

11. *T Herculis.*

Observed from April 18 to May 15, 8 observations; and from September 25 to November 9, 16 observations. The first maximum occurred about April 26, and was apparently a faint one. (Observations interrupted from April 20 to May 2.) Maximum brightness 4 or 5 steps < DM. 30°,3142, or about $8^{M}.5$. The second maximum (which was well observed) occurred on October 5. Maximum brightness 5 steps > DM. 30°,3142, and 1 or 2 steps < DM. 30°,3133, or $7^{M}.4$.

12. *U Herculis.*

This star was under observation from June 1 to September 12, 30 observations being obtained. When first seen, on June 1, *U* was 2 or 3 steps > DM. 19°,3097, and 5 steps < DM. 19°,3094, or $8^{M}.8$. The increase of light was rapid, and a maximum was reached about July 8. Maximum brightness 3 steps > DM. 19°,3092, and 4 steps < DM. 19°,3089, or $7^{M}.8$. The decrease of light also appeared quite rapid, and when last observed, on September 12, *U* was 2 steps > DM. 19°,3097, and 5+ steps < DM. 19°,3094, or $8^{M}.9$.

13. *g Herculis.*

A very fair series of observations was obtained on this star, 65 in number, extending from April 17 to December 12. The fluctuations of light were very decided during this year, as in the last, and 7 maxima and minima were observed. The three maxima occurred on June 4, August 2(?) and October 16, showing an interval of 59 days between the first and second, while the interval between the second and third maximum is considerably longer, or 75 days. The star was again near maximum when the observations ended, December 12. The four minima occurred on April 29, July 5, September 12, and November 18(?). The intervals between the different minima appeared quite regular; or 67 days between the first and second minima, 69 days between the second and third, and 67 days between the third and fourth. The third minimum was a very faint one, and the fourth a bright one.

14. *R Coronae.*

This interesting star was under observation from March 5 to December 2, 70 observations being obtained. *R* was subject to numerous fluctuations of light during the year; but, with a single exception, these fluctuations were slight, 3 or 4 steps only. After an unusually bright phase, which occurred on August 15 (light = DM. 32°,2621, or $6^{M}.2$), *R* quite rapidly decreased, and a rather faint minimum was passed October 13. Light 2 or 3 steps > DM. 28°,2475, and 5 steps < DM. 31°,2771, or $7^{M}.4$. When last observed, December 2, *R* was 5+ steps > DM. 31°2771, and 3 or 4 steps < DM. 30°,2682, or $6^{M}.8$.

15. *S Coronae.*

Observed from April 9 to July 12; 34 observations. When first seen, April 9, *S* was 4 steps > DM. 32°,2577, or $8^{M}.1$. The increase of light was quite uniform, but not very rapid. The maximum occurred May 11. Maximum brightness, 5 steps > DM. 32°,2575 and =DM. 32°,2578, or $7^{M}.7$; this

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being nearly half a magnitude fainter than the maximum of last year. When last observed, on July 12, *S* was 1 or 2 steps < DM. 32°,2573, or about $9^{M}.0$.

16. *β Pegasi.*

This star was under observation from January 10 to February 3, and from July 15 to January 1, 1886; 39 observations being obtained. The light has remained apparently constant.

17. *β Persei.*

One fair determination of a minimum was obtained on December 24, at $7^{h}\,21^{m}$ Camb. M.T. Duration of observation, 3 hours.

18. *ρ Persei.*

The observations on this star were continued (from the series published in *Astr. Nachr.*, no. 2660, and extending to January 1) until April 5, and also from August 15 to January 1, 1886; 36 observations. The light has remained nearly constant, fluctuating not more than two steps, but no decided phases have been observed.

19. *α Cassiopeae.*

Observed from January 10 to March 5, and from August 6 to January 1, 1886; 33 observations. The light has remained apparently constant.

20. *T Monocerotis.*

This star was observed from November 10, 1884, to May 3, 1885; a good series of observations, 80 in number being obtained. From these the following epochs of maxima and minima have been deduced, in Cambridge M.T., using the mean light-curve formed from the 1881-83 observations.

Observed Maxima		d	h	m	Observed Minima		d	h	m
1884	Nov.	17	10	21	1884	Nov.	12	2	50
	Dec.	12	14	32		Dec.	7	3	14
1885	Jan.	10	12	42	1885	Jan.	2	22	23
	Feb.	6	11	5			29	5	36
	Mar.	5	10	2		Feb.	22	18	55
		31	22	11		Mar.	21	11	31
	Apr.	27	15	55		Apr.	20	15	26

21. *U Monocerotis.*

67 observations of this star were obtained, extending from November 21, 1884, to May 10, 1885. Serious breaks occur in the series, notably from November 26 to December 7, December 23 to January 7, and January 21 to February 2, occasioned by cloudy weather. Notwithstanding these breaks in the observations, there appears to be an irregularity in the light-changes, and bright and faint maxima and minima are shown by the light-curve. The following times of maxima and minima have been determined:

Maximum =	1884 Dec. 12.5	Light =	13.2
	1885 Jan. 23		16.2
	March 5		18.2
	April 14		13.3
Minimum =	1885 Jan. 4.5	Light =	—1.7
	Feb. 18		3.8
	April 1.5		3.9

The interval between the 1st and 2d maximum = 41.5 days; between the 2d and 3d maximum = 41 days; and between the 3d and 4th maximum = 40 days. The interval between the 1st and 2d minimum = 44.5 days, and between the 2d and 3d minimum = 42.5 days. The period, apparently, remained quite regular during the year.

22. *χ Cygni.*

This star was under observation from November 17, 1885, to January 26, 1886, 30 observations being obtained. When first seen, on November 17, *χ* was 5 steps < DM. 32°,3589, or about $8^{M}.5$. The increase of light, although quite uniform, was not very rapid. The star passed a maximum 1886 January 10. Maximum brightness, 2 or 3 steps > DM. 33°,3587, and 1 step < DM. 29°,3684, or $5^{M}.3$, this being about the same brightness as the maximum last year. The decrease of light was not well observed, owing to the star's near approach to the sunset horizon. When last seen, January 26, *χ* was 5+ steps > DM. 32°,3531, and 2 steps < DM. 33°,3587, or about $5^{M}.6$. The light at maximum remained apparently stationary from December 30, 1885, to January 17, 1886, 19 days.

23. *R Scuti.*

A fair series of observations (65 in number), was obtained on this star, extending from May 12 to December 11. From these observations 3 maxima and 2 minima have been deduced. The first maximum, a faint one, occurred on June 17, light = 17.2. The second maximum occurred about August 10(?) and was a fairly bright one; light = 20.5. The third maximum (of nearly the same brightness) was passed on November 16; light = 19.0. The interval from 1st to 2d maximum was 54 days, and from 2d to 3d maximum, 67 days. At the third maximum the light remained apparently stationary for 44 days, or from October 24 to November 7. The two minima occurred July 14 and September 24. The first minimum was a bright one, light = 12.0, while the second was a faint one, light = 8.4. The interval between the two minima was 72 days.

24. 36 (*U.A.*) *Ceti;* $0^{h}\,15^{m}\,26^{s}$, —20° 45′.1 (1875.0)

Observed from 1885 September 30, to 1886 February 5; 31 observations. When first seen, on September 30, the star was found to equal 21 (*U.A*) *Ceti*, or $7^{M}.0$. The light remained apparently constant from September 30 to November 2, when a break occurs in the observations until November 27, on which date the star was found to be much brighter and = $6^{M}.0$. The increase of light from November 27 was quite rapid, although irregular. A maximum was passed on 1886 January 9. Maximum brightness = 18 (*U.A.*) *Ceti*, and 5 steps > 7 (*U.A.*) *Ceti*, or $5^{M}.4$. The light at maximum remained apparently constant from December 24, 1885, to January 20, 1886, 28 days. This star is undoubtedly of the *R Scuti* type.

25. *o Ceti.*

A good series of observations was obtained on this star, extending from 1884 October 9 to 1885 March 17; 50 observations.

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The increase of light was very rapid, and a maximum was passed February 10, 1885. Maximum brightness, 5 steps $>\gamma$ *Ceti* and 4 steps $<\alpha$ *Ceti*, or $2^{M}.7$; this representing a rather bright maximum. The light remained apparently constant for the 29 days from January 26 to February 23. The decrease of light could not be followed after March 17, on which day the star was $=\gamma$ *Ceti*, or about $3^{M}.2$.

26. *W* (?) *Cygni* (*Gore* 1885).

$21^{h}\ 30^{m}\ 33^{s}.9 \quad +44^{\circ}\ 43'.7 \quad (1855.0)$

At the request of Mr. Gore, observations were begun on this star June 3, 1885. A few observations soon established the star's variability beyond doubt. The observations were continued until January 26, 1886, and are 68 in number. From the observations, two maxima and one minimum were determined. The first maximum was passed on August 20. Maximum brightness, 3 steps > DM. 44°,3889, and 2 steps < DM. 46°,3305, or about $6^{M}.1$. The second maximum, of about the same brightness, was passed on December 16, giving a period of 118± days, this being about one-half the length of period as first announced by the discoverer. The minimum occurred on October 30. Minimum brightness, 1 or 2 steps > DM. 43°,4002, and 3 or 4 steps < DM. 44°,3889, or about $6^{M}.7$. The light-curve exhibits a rather rapid and uniform increase, with a somewhat less rapid and irregular decrease. Its intense red color renders it rather a difficult object to observe.

27. *R Aquarii.*

Observed from December 4, 1884, to February 3, 1885. The observations, when charted, exhibit a rapid increase and somewhat rapid decrease of light. A maximum was reached 1885 January 4. Maximum brightness = 269 *b* (*U.A.*) *Aquarii*, and 4 steps < 266 (*U.A.*) *Aquarii*, or about $7^{M}.1$.

ELEMENTS OF COMET 1886 *e*.

[FROM A LETTER OF REV. GEORGE M. SEARLE.]

I have computed the following elements for Comet 1886 *e* (*Finlay*), from the discovery-observation September 26, with two others made by myself on November 4 and December 14. They are probably hardly as accurate as they ought to be, on account of the roughness of the two last places. The period cannot however be very much in error.

The middle place is represented as follows:

$$\text{O--C}$$
$$\Delta\lambda = +1'' \qquad \Delta\beta = 0''$$

The $\Delta\lambda$ is within the errors of the tables, as the computation was only made to six places.

$$T = \text{November } 22.3703 \text{ Gr. M.T.}$$
$$\left.\begin{aligned}\pi &= \ \ 7^{\circ}\ 27'\ 37''\\ \Omega &= 52\ \ 24\ \ \ 4\end{aligned}\right\}1886.0$$
$$i = 3\ \ 1\ \ 47$$
$$\log a = 0.553434$$
$$\log e = 9.857847$$
$$\log q = 9.999267$$
$$\text{Period } 6^{y}.7632$$

New York, 1887 *January* 3.

OBSERVATIONS OF THE COMET 1886 *e* (*FINLAY*)

MADE AT THE DUDLEY OBSERVATORY, ALBANY.

(Communicated by the Director, Prof. Lewis Boss.)

Albany M.T.	*	No. Comps.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
1886 Dec. 6 7h 29m 47s	15	12 , 1	−1m 51s.87	−0′ 2″.6	21h 41m 6s.18	−15° 38′ 49″.6	9.487	0.847
16 7 7 42	16	6 , 2	−6 44.78	−0 10.7	22 32 38.54	10 14 29.5	9.396	0.834
9 9 25	17	9 , 3	+1 56.01	0 0.0	22 33 4.29	10 11 30.2	9.527	0.821
17 6 4 26	18	12 , 4	+0 31.82	+3 47.8	22 37 34.86	9 40 56.2	9.139	0.840
6 27 1	19	18 , 6	−0 39.42	−0 54.2	22 37 39.16	9 40 20.3	9.251	0.838
7 17 37	19	27 , 9	−0 28.50	+0 18.0	22 37 50.08	9 39 8.1	9.415	0.830
7 44 56	20	10 , 4	−0 20.85	−1 29.4	22 37 55.82	9 38 25.7	9.480	0.824
8 33 30	21	21 , 7	+1 52.93	−1 31.5	22 53 32.80	7 49 53.6	9.553	0.808
6 2 17	22	10	0 21.20	+0 35.5	22 58 8.86	7 17 18.1	8.894	0.830
7 42 16	23	30 , 10	1 56.18	+1 33.1	23 28 59.01	−3 33 44.2	9.444	0.797
8 20 10	24	21 , 7	+2 24.59	−2 3.6	1 12 58.03	+8 59 37.6	9.493	0.714

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Adopted Mean Places (for 1886.0) of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
15	21 42 59.21	+1.84	−15 39 1.2	+14.2	Wash. (1879) Transit Circle
16	22 39 21.30	2.02	10 14 33.8	15.0	Argent. Gen. Catal. 30987
17	22 28 6.31	1.97	10 11 45.4	15.2	Argent. Gen. Catal. 30775 and Yar. 9908
18	22 37 1.04	2.00	9 44 59.2	15.2	W.B. 752 and Schj. 9294
19	22 38 16.57	2.01	9 39 41.3	15.2	W.B. 776 and Rümk. 10552
20	22 38 14.66	2.01	9 37 11.5	15.2	W.B. 774 and Rümk. 10551
21	22 48 37.85	2.02	7 48 37.4	15.3	Newcomb (St. and Zod.) 1041
22	22 58 28.00	2.06	7 18 8.9	15.3	Schj. 9475, Yarnall 10151, Berlin (A.N. 69, p 78)
23	23 30 53.28	2.21	− 3 35 32.7	15.4	Karlsruhe and Berlin (A.N. 69, p 78)
24	1 10 30.76	+2.68	+ 9 1 27.4	+13.8	Glasgow 303

NOTES.

This series of observations is in continuation of that reported in No. 147 of this Journal. With each of these determinations the filar-micrometer was used. The aperture of the telescope is 13 inches, and the magnifying power employed is 200. On December 6 and 16 fog interfered with the observations. On all other occasions the conditions for observation were at least fair, and on December 17 excellent. There was no opportunity to observe the comet at this Observatory between December 27 and January 18.

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The adopted star-place on December 20 agrees well with the mean of determinations at Pulkowa and Cordoba, published since the compilation of Newcomb's Catalogue.

Weisse 123 does not agree well with position obtained from the Glasgow Catalogue for use on January 18.

The observation of January 18 indicates as corrections to the Ephemeris published in No. 150 of this Journal: $\Delta\alpha, = +2^s.23$; $\Delta\delta = +5''.9$.

NOTE ON AN INACCURACY IN THE DEVELOPMENT OF A DIFFERENTIAL REFRACTION FORMULA.

By S. C. Chandler, Jr.

If it be not considered unnecessary or out of place in the *Journal*, I should like to note a curious error, which has apparently escaped notice hitherto, in the analysis by which the effect of differential refraction is reached in Brünnow's "*Spherical Astronomy*."

By treating the correction in question as composed of two parts, one the same as for the filar-micrometer, the other equivalent to a proper-motion of the stars while passing through the ring, Brünnow gives (Section VII., Art. 45)

$$\Delta(\delta'-\delta) = k(\delta'-\delta)[\tan\zeta^2\cos 2\eta + \tan\zeta\cos\eta\tan\delta]$$
$$-k(\delta'-\delta)\frac{r^2}{(\delta-D)(\delta'-D)}\times(1+\tan\zeta^2\sin\eta^2-\tan\zeta\cos\eta\tan\delta)$$

which, he says, is the "expression of the complete correction of the difference of declination;" adding that "we can, in most cases, neglect the terms multiplied by tan ζ, and thus we obtain simply" eq. (B), which is identical with that of Bessel (compare Chauvenet II., eq. (360)), who reaches it by an entirely different development; namely, through the general formulas for position-angle and distance.

The implication here is that Bessel's form is less exact than the one above given. This, however, is not the fact, as the terms which Brünnow finds it necessary to ignore to produce the ordinary formula have no existence. It may be of service to students of practical astronomy at least, to point out the inadvertence through which the erroneous terms are introduced.

In adapting the formulas for proper-motion to the case of the refraction, the expression $d^2 = r^2 - (15t\cos\delta)^2$ in Art. 36 should have been differentiated with reference to both t and δ, so that instead of eq (A) of that article, we have

$$\Delta d = \frac{\mu^2}{d}\left(\frac{\Delta\alpha}{15} + \Delta\delta\tan\delta\right)$$

The value of $\Delta\delta$ here is $\beta\tan\zeta\cos\eta$; but we may put $k=\beta$ with sufficient precision, since in eq. (A) of Art. 42, $\frac{d\zeta}{dz}$ is nearly unity and $\frac{\Delta\delta}{d\zeta}$ is very small. Consequently for the erroneous value of $\Delta\delta$ given in Art. 45, we must substitute

$$\Delta\delta = \frac{\mu^2}{\delta-D}(h + k\tan\zeta\cos\eta\tan\delta]$$

If this is carried through the development, the terms in tan ζ, in the equation near the beginning of this note, vanish, and it is left in the precise form Bessel has given.

Cambridge, 1886 *December* 20.

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The increase of light was very rapid, and a maximum was passed February 10, 1885. Maximum brightness, 5 steps $>\gamma$ *Ceti* and 4 steps $<\alpha$ *Ceti*, or $2^{\text{M}}.7$; this representing a rather bright maximum. The light remained apparently constant for the 29 days from January 26 to February 23. The decrease of light could not be followed after March 17, on which day the star was $=\gamma$ *Ceti*, or about $3^{\text{M}}.2$.

26. *W* (?) *Cygni* (*Gore* 1885).

$21^{\text{h}}\ 30^{\text{m}}\ 33^{\text{s}}.9 \quad +44^\circ\ 43'.7$ (1855.0)

At the request of Mr. Gore, observations were begun on this star June 3, 1885. A few observations soon established the star's variability beyond doubt. The observations were continued until January 26, 1886, and are 68 in number. From the observations, two maxima and one minimum were determined. The first maximum was passed on August 20. Maximum brightness, 3 steps $>$ DM. 44°,3889, and 2 steps $<$ DM. 46°,3305, or about $6^{\text{M}}.1$. The second maximum, of about the same brightness, was passed on December 16, giving a period of 118$\pm$ days, this being about one-half the length of period as first announced by the discoverer. The minimum occurred on October 30. Minimum brightness, 1 or 2 steps $>$ DM. 43°,4002, and 3 or 4 steps $<$ DM. 44°,3889, or about $6^{\text{M}}.7$. The light-curve exhibits a rather rapid and uniform increase, with a somewhat less rapid and irregular decrease. Its intense red color renders it rather a difficult object to observe.

27. *R Aquarii.*

Observed from December 4, 1884, to February 3, 1885. The observations, when charted, exhibit a rapid increase and somewhat rapid decrease of light. A maximum was reached 1885 January 4. Maximum brightness = 269 *b* (*U.A.*) *Aquarii*, and 4 steps $<$ 266 (*U.A.*) *Aquarii*, or about $7^{\text{M}}.1$.

ELEMENTS OF COMET 1886 *e*.

[FROM A LETTER OF REV. GEORGE M. SEARLE.]

I have computed the following elements for Comet 1886 *e* (*Finlay*), from the discovery-observation September 26, with two others made by myself on November 4 and December 14. They are probably hardly as accurate as they ought to be, on account of the roughness of the two last places. The period cannot however be very much in error.

The middle place is represented as follows:

$$\text{O--C}$$
$$\Delta\lambda = +1'' \qquad \Delta\beta = 0''$$

The $\Delta\lambda$ is within the errors of the tables, as the computation was only made to six places.

$$T = \text{November } 22.3703 \text{ Gr. M.T.}$$
$$\left.\begin{aligned}\pi &= 7^\circ\ 27'\ 37''\\ \Omega &= 52\ \ 24\ \ \ 4\end{aligned}\right\}\ 1886.0$$
$$i = 3\ \ \ 1\ 47$$
$$\log a = 0.553434$$
$$\log e = 9.857847$$
$$\log q = 9.999267$$
$$\text{Period } 6^{\text{y}}.7632$$

New York, 1887 *January* 3.

OBSERVATIONS OF THE COMET 1886 *e* (*FINLAY*)

MADE AT THE DUDLEY OBSERVATORY, ALBANY.

(Communicated by the Director, Prof. Lewis Boss.)

Albany M.T.	*	No. Comps.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s			m s	' ''	h m s	° ' ''		
1886 Dec. 6 7 29 47	15	12 , 4	−1 54.87	−0 2.6	21 41 6.18	−15 38 49.6	9.487	0.847
16 7 7 42	16	6 , 2	−6 44.78	−0 10.7	22 32 38.54	10 14 29.5	9.396	0.834
9 9 25	17	9 , 3	+4 56.01	0 0.0	22 33 4.29	10 11 30.2	9.527	0.821
17 6 4 26	18	12 , 4	+0 31.82	+3 47.8	22 37 34.86	9 40 56.2	9.139	0.840
6 27 1	19	18 , 6	−0 39.42	−0 54.2	22 37 39.16	9 40 20.3	9.251	0.838
7 17 37	19	27 , 9	−0 28.50	+0 18.0	22 37 50.08	9 39 8.1	9.415	0.830
7 44 56	20	10 , 4	−0 20.85	−1 29.4	22 37 55.82	9 38 25.7	9.480	0.824
20 8 33 30	21	21 , 7	+4 52.93	−1 31.5	22 53 32.80	7 49 53.6	9.553	0.808
21 6 2 17	22	10	−0 21.20	+0 35.5	22 58 8.86	7 17 18.1	8.894	0.830
27 7 42 16	23	30 , 10	−1 56.48	+1 33.1	23 28 59.01	− 3 33 44.2	9.444	0.797
1887 Jan. 18 8 20 10	24	21 , 7	+2 24.59	−2 3.6	1 12 58.03	+ 8 59 37.6	9.493	0.714

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Adopted Mean Places (for 1886.0) of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
15	21 42 59.21	+1.84	−15 39 1.2	+14.2	Wash. (1879) Transit Circle
16	22 39 21.30	2.02	10 14 33.8	15.0	Argent. Gen. Catal. 30987
17	22 28 6.31	1.97	10 11 45.4	15.2	Argent. Gen. Catal. 30775 and Yar. 9908
18	22 37 1.04	2.00	9 44 59.2	15.2	W.B. 752 and Schj. 9294
19	22 38 16.57	2.01	9 39 41.3	15.2	W.B. 776 and Rümk. 10552
20	22 38 14.66	2.01	9 37 11.5	15.2	W.B. 774 and Rümk. 10551
21	22 48 37.85	2.02	7 48 37.4	15.3	Newcomb (St. and Zod.) 1041
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The value of $\Delta\delta$ here is $\beta\tan\zeta\cos\eta$; but we may put $k=\beta$ with sufficient precision, since in eq. (A) of Art. 42, $\frac{d\zeta}{dz}$ is nearly unity and $\frac{\Delta\delta}{d\zeta}$ is very small. Consequently for the erroneous value of $\Delta\delta$ given in Art. 45, we must substitute

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Cambridge, 1886 *December* 20.

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RING-MICROMETER [illegible] OF COMET 1886 e (FINLAY)

[illegible]

[illegible]	δ	log pΔ for α	log pΔ for δ
[illegible]	—2[illegible] [illegible] 7.4	9.474	.878
[illegible]	[illegible] [illegible] 42.6	9.497	.873
[illegible]	[illegible] [illegible] 4[illegible].9	9.477	.877
[illegible]	[illegible] [illegible] 51.9	9.508	.871
[illegible]	[illegible] 2[illegible] 58.7	9.474	.878
[illegible]	[illegible] 2[illegible] 48.8	9.464	.879
[illegible]	23 [illegible] 6.8	9.417	.877
[illegible]	2[illegible] 24 59.7	9.427	.875
[illegible]	2[illegible] 9 51.7	9.438	.873
[illegible]	22 38 9.0	9.324	.882
[illegible]	22 20 34.7	9.402	.874
[illegible]	22 3 8.6	9.365	.877
[illegible]	[illegible]	9.421	.870
[illegible]	20 1 2.2	9.396	.866
[illegible]	19 38 10.5	9.383	.866
[illegible]	8 28 53.9	9.228	.819
[illegible]	—3 34 55.2	9.306	.784

[illegible] Comparison-Stars.

[illegible]	[illegible]	Authority
[illegible]	[illegible]	Z.C. 17ʰ, 3977
[illegible]	[illegible]	E., Comp. with G.C. 24919
[illegible]	[illegible]	Z.C. 18ʰ, 1071
[illegible]	[illegible]	Z.C. 18, 1257
[illegible]	[illegible]	Z.C. 18, 1501
[illegible]	[illegible]	Z.C. 18, 1543
[illegible]	[illegible]	Z.C. 19, 2120
[illegible]	[illegible]	Z.C. 19, 2286
[illegible]	[illegible]	Z.C. 20, 72
[illegible]	12.1	Wash. M.C. Zones 186,4
[illegible]	12.2	Oe. Argel. 20436
[illegible]	12.2	Oe. Argel. 20485
[illegible]	12.4	
[illegible]	13.3	Oe. Argel. 21057
[illegible]	1[illegible].3	Yarnall 9198
[illegible]	15.2	W. Bessel 22ʰ, 1002
[illegible]	15.6	W. Bessel 23, 511

NOTE ON A STAR-POSITION IN YARNALL'S WASHINGTON CATALOGUE.

[illegible] has arisen in [illegible] YARNALL's Catalogue, where it ap- [illegible] about 42″ to the south, and also to have been mistaken for a close double. The right-ascension of No. 7815′ should stand as it is in YARNALL's Catalogue, but the declination should read —26° 40′ 38″.9; mean year, 76.3; number of observations, 3. No. 7816 should be stricken out, and No. 7816′ should read:

18ʰ 20ᵐ 13ˢ.83 72.2 7 | 3.740 | —26° 39′ 54″.9 | 68.9 6 | 1.77

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It appears also that on page XVIII. of the introduction of YARNALL's Catalogue (second edition), the author inadvertently omitted to insert after "1872," in line 15, the words: "and subsequent years." The oversight is undoubtedly due to the fact that the statement cited was correct for the first edition, but does not apply to the second edition which contains later material of observation.

I have looked up the position of this star in a few catalogues, and herewith submit the result:

Catalogue No.	R.A. 1886.0	No. Obs.	Decl. 1886	No. Obs.
Lacaille 7732	$18^h\ 21^m\ 51^s.9$	1	$-26°\ 39'\ 8''.$	1
Lalande 34037 Von Asten's Tables.	51.03	1	6.	1
Oeltzen's Argel. 18262	51.08	1	5.8	1
Cape (1850) 3572	51.16	2	7.4	2
Arg. Gen. Cat. 25197	51.06	8	8.6	8
Washington 7816	51.07	7	7.1	6
Cape (1880) 10006	50.92	3	7.5	3
Adopted position, 1886.0,	18 21 51.06		—26 39 7.7	

This star appears to have no sensible proper-motion.

1886 *December* 21.

LEWIS BOSS.

ELEMENTS OF COMET 1886 γ (*BARNARD*)

BY LIEUT. WILLIAM H. ALLEN, U.S. NAVY.

[Communicated by the Superintendent of the Naval Observatory, Washington.]

By means of an approximate set of elements, four normal positions of this comet were formed and referred to the mean equinox of 1886.0.

1886 Berlin M.T.	α	δ	No. Obs.
Oct. 8.0	160° 33′ 43″.5	+ 1° 23′ 0″.4	11
Nov. 3.5	179 12 43 .8	7 15 58 .1	4
Dec. 2.5	231 35 46 .5	17 56 39 .4	2
Dec. 10.0	252 26 41 .0	+16 57 40 .2	2

The method of the variation of the geocentric distances gave the following elements:

$$T = 1886 \text{ Dec. } 16.54300 \text{ Berlin M.T.}$$
$$\left.\begin{aligned} \omega &= 86°\ 21'\ 33''.1 \\ \Omega &= 137\ \ 22\ \ 36\ .8 \\ i &= 101\ \ 36\ \ 55\ .5 \end{aligned}\right\} \text{Mean Eq. 1886.0}$$
$$\log q = 9.821628$$

1887 *January* 8.

The residuals of the normals are, (C—O),

	$\Delta\alpha \cos\delta$	$\Delta\delta$
Oct. 8.0	+ 0″.2	+ 0″.3
Nov. 3.5	+ 3 .7	− 7 .2
Dec. 2.5	—10 .0	—25 .2
Dec. 10.0	— 0 .6	— 0 .8

The equations for the rectangular coordinates referred to the equator, and mean equinox 1886.0, are

$$x = r\ (9.8741044) \sin (v + \ \ 6°\ 51'\ 23''.9)$$
$$y = r\ (9.8268043) \sin (v + 198\ \ 35\ \ 36\ .6)$$
$$z = r\ (9.9977216) \sin (v + 102\ \ \ 4\ \ 46\ .2)$$

From the representation of the normals there does not appear to be much evidence of eccentricity in this orbit. The last two positions depend on observations made at Washington.

THREE NEW COMETS.

a

Dr. KRUEGER has forwarded the following telegrams from Kiel, by the *Science Observer* code:

January 24. "Comet discovered by THOME, at Cordoba, January 18. It will become very brilliant. Constellation *Grus*. Physical appearance resembles comet of 1880."

January 25. "Southern comet observed at Melbourne roughly, as follows:

Jan. 23.000 Greenw. M.T. $\alpha = 21^h\ 20^m\ 28^s$ $\delta = -44°\ 17'$

Daily motion $+7^m\ 0^s$ in α, and 51′ southward."

A later despatch from Dr. KRUEGER says: "Orbit of Southern comet presents a close resemblance to that of first comet of 1880. Perihelion, January 11."

b

The morning papers of January 23 contained an announcement of the discovery of a faint comet, in the constellation *Draco*, by Mr. BROOKS, at Phelps, N.Y., on the previous evening. He gave its place at 7 p.m., as about 18^h in right-ascension, and +71° in declination: with slow eastwardly motion.

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RING-MICROMETER OBSERVATIONS OF COMET 1886 *e* (FINLAY)

MADE AT THE LEHIGH UNIVERSITY OBSERVATORY

By C. L. DOOLITTLE.

1886		Greenwich M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
		h m s			m s	′ ″	h m s	° ′ ″		
Oct.	16	11 44 29.6	a	6	—0 17.69	+ 8 36.7	17 58 53.52	—26 39 7.4	9.474	.878
	20	11 57 26.2	b	6	+0 24.57	+11 20.9	18 12 25.90	26 35 42.6	9.497	.873
	21	11 42 54.6	c	6	—1 41.55	— 0 55.1	18 15 53.91	26 33 49.9	9.477	.877
	22	11 55 22.0	d	6	—1 32.38	+17 25.4	18 19 28.67	26 31 51.9	9.508	.871
	23	11 41 3.0	e	6	—2 7.40	+ 4 30.0	18 23 2.25	26 29 38.7	9.474	.878
	24	11 37 13.8	f	6	+0 37.32	—10 50.5	18 26 39.30	26 26 48.8	9.464	.879
Nov.	14	11 27 35.9	g	6	+1 1.35	— 0 37.6	19 53 15.75	23 39 6.8	9.417	.877
	15	11 32 13.3	h	6	+1 7.25	— 8 46.4	19 57 51.48	23 24 59.7	9.427	.875
	16	11 36 50.5	i	6	—0 7.03	+ 2 10.0	20 2 28.86	23 9 51.7	9.438	.873
	18	11 4 29.4	k	6	+0 17.93	—17 22.2	20 11 43.14	22 38 9.0	9.324	.882
	19	11 27 55.5	l	6	+1 3.81	— 1 53.1	20 16 30.89	22 20 34.7	9.402	.874
	20	11 17 31.0	m	6	+2 18.90	— 1 34.0	20 21 13.62	22 3 8.6	9.365	.877
	21	11 36 19.3	n	6	—0 45.51	— 3 39.5			9.421	.870
	26	11 34 30.2	o	6	—6 13.54	—15 24.6	20 50 26.73	20 1 2.2	9.396	.866
	27	11 31 42.2	p	6	—0 54.66	+ 3 23.3	20 55 23.42	19 38 10.5	9.383	.866
Dec.	19	11 23 10.2	q	6	—1 52.38	— 3 28.4	22 47 56.58	8 28 53.9	9.228	.819
	27	11 51 51.7	r	6	+1 44.35	+ 3 34.3	23 28 50.40	— 3 34 55.2	9.306	.784

Mean Places for 1886.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
a	17 59 9.50	1.71	—26 47 51.0	6.9	Z.C. 17h, 3977
b	18 11 59.62	1.71	26 47 11.0	7.5	Eq. Comp. with G.C. 24919
c	18 17 33.74	1.72	26 33 2.5	7.7	Z.C. 18h, 1071
d	18 20 59.33	1.72	26 49 25.0	7.7	Z.C. 18 , 1257
e	18 25 7.94	1.71	26 34 16.7	8.0	Z.C. 18 , 1501
f	18 26 0.29	1.69	26 16 6.4	8.1	Z.C. 18 , 1543
g	19 52 12.71	1.69	23 38 40.6	11.4	Z.C. 19 , 2120
h	19 56 42.53	1.70	23 16 24.9	11.6	Z.C. 19 , 2286
i	20 2 34.17	1.72	23 12 13.4	11.7	Z.C. 20 , 72
k	20 11 23.50	1.71	22 20 58.9	12.1	Wash. M.C. Zones 186,4
l	20 15 25.36	1.72	22 18 53.8	12.2	Oe. Argel. 20436
m	20 18 53.00	1.72	22 1 46.8	12.2	Oe. Argel. 20485
n		1.73		12.4	
o	20 56 38.50	1.77	19 45 50.9	13.3	Oe. Argel. 21057
p	20 56 16.31	1.77	19 41 47.1	13.3	Yarnall 9198
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r	23 27 3.86	2.19	— 3 38 45.1	15.6	W. Bessel 23 , 511

Bethlehem, Pennsylvania, 1887 *January* 13.

NOTE ON A STAR-POSITION IN YARNALL'S WASHINGTON CATALOGUE.

The Star, No. 7732 of LACAILLE, was used, on October 23 of this year, both at Rome and at Washington, in comparison with the FINLAY comet. The Washington observations contain seven determinations of the right-ascension, and six of the declination of this star. Some confusion has arisen in regard to this object in YARNALL'S Catalogue, where it appears to become entangled with the small star about 42″ to the south, and also to have been mistaken for a close double. The right-ascension of No. 7815′ should stand as it is in YARNALL'S Catalogue, but the declination should read —26° 40′ 38″.9; mean year, 76.3; number of observations, 3. No. 7816 should be stricken out, and No. 7816′ should read:

18h 20m 13s.83 | 72.2 | 7 | 3.740 | —26° 39′ 54″.9 | 68.9 , 6 | 1.77

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It appears also that on page XVIII. of the introduction of YARNALL's Catalogue (second edition), the author inadvertently omitted to insert after "1872," in line 15, the words: "and subsequent years." The oversight is undoubtedly due to the fact that the statement cited was correct for the first edition, but does not apply to the second edition which contains later material of observation.

I have looked up the position of this star in a few catalogues, and herewith submit the result:

1886 *December* 21.

Catalogue No.	R.A. 1886.0	No. Obs.	Decl. 1886	No. Obs.
Lacaille 7732	$18^h\ 21^m\ 51^s.9$	1	—26° 39′ 8″.	1
Lalande 34037 Von Asten's Tables.	51.03	1	6.	1
Oeltzen's Argel. 18262	51.08	1	5.8	1
Cape (1850) 3572	51.16	2	7.4	2
Arg. Gen. Cat. 25197	51.06	8	8.6	8
Washington 7816	51.07	7	7.1	6
Cape (1880) 10006	50.92	3	7.5	3
Adopted position, 1886.0,	18 21 51.06		—26 39 7.7	

This star appears to have no sensible proper-motion.

LEWIS BOSS.

ELEMENTS OF COMET 1886 ♈ (*BARNARD*)

BY LIEUT. WILLIAM H. ALLEN, U.S. NAVY.

[Communicated by the Superintendent of the Naval Observatory, Washington.]

By means of an approximate set of elements, four normal positions of this comet were formed and referred to the mean equinox of 1886.0.

1886 Berlin M.T.	α	δ	No. Obs.
Oct. 8.0	160° 33′ 43″.5	+ 1° 23′ 0″.4	11
Nov. 3.5	179 12 43 .8	7 15 58 .1	4
Dec. 2.5	231 35 46 .5	17 56 39 .4	2
Dec. 10.0	252 26 41 .0	+16 57 40 .2	2

The method of the variation of the geocentric distances gave the following elements:

$$T = 1886 \text{ Dec. } 16.54300 \text{ Berlin M.T.}$$

$$\left.\begin{aligned} \omega &= 86°\ 21'\ 33''.1 \\ \Omega &= 137\ \ 22\ \ 36\ .8 \\ i &= 101\ \ 36\ \ 55\ .5 \end{aligned}\right\} \text{Mean Eq. 1886.0}$$

$$\log q = 9.821628$$

1887 *January* 8.

The residuals of the normals are, (C—O),

	$\Delta\alpha \cos\delta$	$\Delta\delta$
Oct. 8.0	+ 0″.2	+ 0″.3
Nov. 3.5	+ 3 .7	— 7 .2
Dec. 2.5	—10 .0	—25 .2
Dec. 10.0	— 0 .6	— 0 .8

The equations for the rectangular coordinates referred to the equator, and mean equinox 1886.0, are

$$\begin{aligned} x &= r\,(9.8741044)\sin(v + \ \ 6°\ 51'\ 23''.9) \\ y &= r\,(9.8268043)\sin(v + 198\ \ 35\ \ 36\ .6) \\ z &= r\,(9.9977216)\sin(v + 102\ \ \ 4\ \ 46\ .2) \end{aligned}$$

From the representation of the normals there does not appear to be much evidence of eccentricity in this orbit. The last two positions depend on observations made at Washington.

THREE NEW COMETS.

a

Dr. KRUEGER has forwarded the following telegrams from Kiel, by the *Science Observer* code:

January 24. "Comet discovered by THOME, at Cordoba, January 18. It will become very brilliant. Constellation *Grus*. Physical appearance resembles comet of 1880."

January 25. "Southern comet observed at Melbourne roughly, as follows:

Jan. 23.000 Greenw. M.T. $\alpha = 21^h\ 20^m\ 28^s$ $\delta = -44°\ 17'$

Daily motion $+7^m\ 0^s$ in α, and 51′ southward."

A later despatch from Dr. KRUEGER says: "Orbit of Southern comet presents a close resemblance to that of first comet of 1880. Perihelion, January 11."

b

The morning papers of January 23 contained an announcement of the discovery of a faint comet, in the constellation *Draco*, by Mr. BROOKS, at Phelps, N.Y., on the previous evening. He gave its place at 7 p.m., as about 18^h in right-ascension, and +71° in declination: with slow eastwardly motion.

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Prof. Boss communicates an observation, made by himself, as follows:

Albany M.T.	No. Comp's	☄—* $\Delta\alpha$	☄—* $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
Jan. 24, $14^h\ 22^m\ 49^s$	21 , 7	$+5^m\ 14^s.36$	$+3'\ 5''.1$	$18^h\ 23^m\ 26^s.17$	$+73°\ 53'\ 30''.9$	$n0.149$	0.642

Mean Place for 1887.0 of Comparison-Star.

α	Red.	δ	Red.	
$18^h\ 18^m\ 15^s.74$	$-3^s.93$	$+73°\ 50'\ 28''.1$	$-2''.3$	DM. 73°,817; Bonn VI.

The Editor is indebted to Mr. Ritchie for an early copy of the *Science Observer Circular* containing the following additional observations:

	Greenw. M.T.	App. α	App. δ	Observer
Washington,	Jan. 24.6503	$18^h\ 21^m\ 51^s.0$	$+73°\ 45'\ 28''$	Frisby
Cambridge,	24.7657	18 22 58 .9	73 51 29	Wendell

The Superintendent of the Washington Observatory has also communicated the later observation:

25.6496	18 33 11 .1	74 37 26	Frisby

The very close proximity of the place of this comet at discovery to the locus of probable positions for the same date, given by Ginzel's sweeping-ephemeris for the periodic comet of 1815, gave rise at first to suspicions of identity, which were however soon dispelled.

c

A comet was detected on the morning of January 24, by Prof. Barnard, at Nashville, Tenn. He describes it as of about the tenth magnitude, and gives its place as follows:

Jan. 23, $23^h\ 52^m$ Greenw. M.T. $19^h\ 7^m\ 48^s$ $+25°\ 24'$

The *Science Observer Circular* gives the additional observations:

	Greenw. M.T.	α	δ	Observer
Cambridge,	Jan. 24.9442	$19^h\ 10^m\ 17^s.4$	$+25°\ 57'\ 45''.1$	Wendell
Albany,	24.9578	19 10 20 .0	25 58 15	Egbert

Comet, circular, about 1′ in diameter, with some central condensation.

CORRIGENDA.

No. 148, p. 29. In equations (119) and (121) a, supply the second ~~number~~, = 0. number

p. 30. In col. 1, line 2, for +6.15 read +0.15.

p. 32. In col. 2, line 3, for 1448 read 2448.

No. 150, p. 46. The Ephemeris is for Greenwich mean midnight, and was so marked by Prof. Boss, although the heading was accidentally omitted in the printed copy.

p. 48. In col. 1, line 34, for $<p$ read $>p$.

In col. 2, lines 11 to 15, the light-equation was inadvertently applied with wrong sign, in forming the series of heliocentric mean times. In line 17, a better value for the epoch would be Dec. $9^d\ 6^h\ 19^m$.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 152.

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SECOND LIST OF NEBULAS OBSERVED AT THE LEANDER McCORMICK OBSERVATORY, AND SUPPOSED TO BE NEW.

BY PROF. ORMOND STONE, DIRECTOR OF THE OBSERVATORY.

No.	R.A. 1890.0	Decl. 1890.0	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° ′		′					
274	0 0.3	—14 1	15.4	0.5	pE 130°	sbMN	1	L	∗15, sf 3^s } D, P 100° Δ 0′.3
275	0 0.3	14 1	15.0	0.2	R	sbMN	1	L	neb?
276	0 3.5	12 44	13.5	0.1	iR		1	M	∗∗9.5, P 280° Δ 2′.0
277	0 5.7	12 37	14.5	0.6	R	sbMN	1	M	∗14.5, P 50° Δ 0′.6
278	0 12.4	23 30	14.5	0.2	R	gbM	1	M	1st of 2
279	0 12.5	23 34	14.5	1.0×0.3	E 225°		1	M	2d of 2; ∗9, P 5° Δ 1′.2
280	0 14	—23 8	15.3	0.2	iF		1	M	∗?; ∗9, P 280° Δ 2′.8
281	0 21	— 3 14	vF	vS	R	lbM	1	L	∗8.5, p 36^s n 2′; α doubtful
282	0 26	23 14	15.0	0.3	lE 100°		1	M	1st of 3; ∗∗11, n 0′.5
283	0 26	23 11	15.0	0.3×0.1	mE 190°		1	M	2d of 3
284	0 26	23 16	14.8	0.2	R		1	M	3d of 3
285	0 31.0	14 13	15.3	0.4	lE 170°		1	L	∗11, np 16^s
286	0 31.0	23 59	14.0	0.8	iR	gbM	1	L	
287	0 31.0	23 13	15.0	0.3×0.1	E 30°		1	M	∗10, P 30° Δ 3′.2
288	0 31.5	23 13	15.8	1.0×0.3			1	M	
289	0 32.0	23 11	14.7	0.2×0.1	E 175°		1	M	∗?
290	0 32.1	—18 27	15.5	0.1	R		1	L	L∗ np
291	0 37.2	—24 13	16.0	0.1	R	bMN	1	L	
292	0 37.5	24 10	15.0	0.5	R	bMN	1	L	
293	0 37.7	24 8	15.0	0.5	R	bMN	1	L	
294	0 45.5	23 18	16.0	0.8×0.3	E 265°		1	M	∗11, P 10° Δ 3′.2
295	0 52	21 26	14.5	0.7	E 160°	sbMN	1	L	env 15.5; ∗10 n
296	0 53	3 19	15.5	0.3	R	lbM	1	L	∗12, nf 3′; α doubtful
297	0 55.5	23 49	16.0	0.4	iR	sbMN	1	M	∗?; 1st of 2
298	0 55.5	23 50	16.0	0.3	iR	sbMN	1	M	∗?; 2d of 2
299	0 59.4	12 44	16.0	1.0×0.2	E 175°	bn	1	M	3 st 12, np 30^s
300	1 5.3	—18 45	16.0	0.1	R		1	L	
301	1 5	— 3 24	16.0	0.8	vlE 170°		1	L	α doubtful
302	1 15.1	22 57	16.3	0.1	R	sbMN	1	L	
303	1 15.4	9 48	14.6	0.4	R	gbMN	2	L	∗12.5, np 1′; ∗12, nf 2′
304	1 15.5	10 27	15.8	0.2	R		1	L	neb?
305	1 21.5	23 18	15.0	0.2×0.1	E 175°		1	M	1st of 3; ∗11, P 75° Δ1′.6
306	1 21.5	23 20	15.5	0.5	iR		1	M	2d of 3
307	1 21.5	23 16	15.5	0.2	R		1	M	3d of 3
308	1 25.6	18 55	15.5	0.3	R		1	L	
309	1 26.4	12 36	13.5	0.3	R	gbMN	1	M	∗10, P 240° Δ 2′
310	1 27.6	—12 46	13.0	0.8	R	gbM	1	M	
311	1 27.9	—12 47	14.5	0.2	R	gbMN	1	M	f(310), P 115° Δ 4′
312	1 29	—20 43	15.0	0.2	R	vgbM	1	M	∗10, P 280° Δ 2′.4

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No.	R.A. 1890.0	Decl. 1890.0	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° ′							
313	1 29	—20 42	eF	vS			1	M	f(312), P 60° Δ 0′.5 ; vF*?
314	1 29.7	10 21	14.5	0.5	lE 160°		1	L	env 15.5
315	1 34.1	9 57	15.8	0.6	lE 170°	lbMN	1	L	*10, s 4′
316	1 34.8	9 49	15.0	1.2	lE 160°	bMN	1	L	1st of 2 ; *8, f 16^s
317	1 35.0	9 50	15.8	0.4	pE 180°	bM$*_*$?	1	L	2d of 2
318	1 39.5	23 30	15.5	0.3	R		1	M	*10, P 320° Δ 1′.6
319	1 45.4	12 35	16.0	1.0×0.4	E 105°	bnp	1	M	curved ; *9.5, p 22^s
320	1 46.6	— 9 38	15.7	0.8×0.3	E 90°	glbMN	1	L	*14, np 2′
321	1 50.8	—10 0	15.8	0.8	lE 180°		1	L	
322	1 51	3 36	vF	vS	R?		1	L	α doubtful
323	1 52.8	10 6	16.0	1.3×0.3	E 160°		1	L	
324	1 59.4	9 38	15.6	0.1	R		1	L	neb? ; *10, s 1′
325	2 4.0	22 35	14.0	0.4	R	gbMN	1	M	
326	2 4	22 58	15.5	0.8	vE 0°		1	L	*10, n 1′
327	2 5.1	22 52	14.8	0.5	R		1	L	neb?
328	2 8.1	23 1	16.0	1.3	R?		1	L	
329	2 11.1	23 42	15.5	0.3×0.1	E 170°		1	M	$*_*$? ; *10, P 320° Δ 2′.8
330	2 12.2	—23 54	15.7	0.2	R		1	L	
331	2 12.4	— 9 29	16.0	0.8	iR	bM (N?)	1	L	
332	2 12.8	4 44	15.8	0.2	R	sbMN	1	L	
333	2 15.4	23 38	16.0	0.1	E?		1	L	neb?
334	2 17.9	9 14	16.0	0.1	R		1	L	*?? ; *9, p 20^s
335	2 21.2	12 35	15.3	0.6×0.2	E 170°		1	M	*8.5, P 15° Δ 3′.8
336	2 23.9	22 52	16.3	0.4	E 0°		1	L	$*_*$??
337	2 25.8	9 47	15.5	0.2	R		1	L	neb? ; *9, sp 30^s
338	2 25.8	7 24	15.5	1.5×1.0	E 230°		1	S	*10 at end
339	2 26.3	4 43	15.5	0.5	R	gbM	1	L	r
340	2 27	—20 22	15.0		R		1	L	*9, sp 2′
341	2 29.3	— 9 17	13.8	vS	R	bMN	1	L	env 16.0 ; N 0′.1
342	2 32.5	10 0	15.0	0.1	iR		1	M	1st of 2
343	2 32.7	9 59	15.0	0.2×0.1	E 180°		1	M	2d of 2
344	2 33.7	9 16	15.5	1.5	iE 190°	sbMN	1	L	
345	2 36.8	9 50	16.0	0.5	R		1	L	
346	2 37.7	9 15	15.3	0.3×0.1	pE 180°		1	L	*10, p 16^s ; *9, f 15^s
347	2 39.1	9 54	15.5	0.1	R		1	M	*9.5, f 30^s s 2′, same as (345) ?
348	2 42.5	22 41	15.7	0.2	R		1	L	
349	2 43.5	8 17	15.8	2.8×0.3	E 348°		1	L	
350	2 47.4	— 9 16	14.0	0.3×0.2	lE 45°		1	L	*12, np 3′ ; *12, nf 2′
351	2 49.8	— 9 34	15.0	0.4×0.2	E 180°		1	M	*9.5, f 25^s n 1′
352	2 52.2	8 7	16.0	0.5	E 135°		1	L	fan-shaped, radiating from * 14
353	2 57.5	9 34	15.7	0.8	pE 15°		1	L	
354	3 0.0	6 55	15.5	0.3			1	S	wide $*_*$, P 45° Δ 4′
355	3 0.7	9 16	15.6	0.2	vlE 180°		1	L	
356	3 3.1	4 41	15.5	0.2×0.1	E 170°		1	L	*P 175°
357	3 3.6	4 34	15.0	0.3	R	gbMN	1	L	1st of 2
358	3 3.8	4 31	15.5	0.2	R		1	L	2d of 2
359	3 4.3	23 21	15.5	0.1	R	gbM	1	L	1st of 2
360	3 4.3	—23 24	16.0	0.1	R	gbM	1	L	2d of 2
361	3 4.5	—23 26					1	L	*??
362	3 5.0	8 16	16.2	0.6	iR		1	L	1 or 2 eF st inv ; *9, p 30^s
363	3 5.4	9 5	13.0	0.4	E 170°		1	M	$*_*$?
364	3 9.4	22 12	15.6	1.2	vlE 0°		2	L	G.C. 665, s 12′
365	3 14.2	13 28	15.3	0.2	R		1	L	
366	3 16.8	4 57	15.3	0.2	R		1	L	*9.5, f 8^s n 3′
367	3 18.3	4 34	16.0	2.0	E 170°		1	L	*10, with eF neb s ; *16 in M?
368	3 20.6	4 31	14.5	0.1	R	bMN	1	L	
369	3 25.0	—22 39	16.0	1.0×0.8	E 130°	sbMN	1	L	

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No.	R.A. 1890.0	Decl. 1890.0	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° '							
370	3 29.1	— 6 37	15.5	0.1		gbMN	1	S	
371	3 29.7	—10 12	14.5	0.5	vlE 170°		2	M	P 75° Δ 2'.5 with neb disc by Burnham
372	3 33.2	19 24	14.0	1.0×0.6	E 260°		1	M	
373	3 33.5	18 42	15.4	0.4	R	gbMN	1	L	1st of 3, one of which is G.C. 742
374	3 33.7	18 38	14.5	0.4×0.2	E 170°	sbMN	1	L	3d of 3
375	3 34.6	22 45	14.0	0.1			1	L	neb*
376	3 34.6	18 53	15.0	0.2	R	gbM	1	L	
377	3 36.1	22 5	15.8	1.6×0.1	E 0°	bMN	1	L	
378	3 36.2	23 8	15.5	0.5	R		1	M	*8.7, nr ; *8.6, n 2'
379	3 37.6	22 3	15.5	0.8×0.2	E 80°		1	L	
380	3 38.5	—18 35	15.4	0.6×0.4	E 20°	sbMN	2	L	
381	3 38.1	— 5 4	15.2	0.2	R	gbM	1	L	1st of 2, one of which is G.C. 763 ; *10, p 15^s
	3 38.6	5 4	15.5	0.3×0.2	E 180°	gbMN	1	L	2d of 2
382	3 39.1	10 2	15.3	0.4	R		1	M	*8.5, f 25^s n 3'
383	3 40.4	10 12	14.5	0.3	R		1	M	*9, P 330° Δ 2'
384	3 40.5	9 23	14.5	0.4	R		1	L	neb? ; *7.5, f 13^s n 1'
385	3 41	21 2	14.5	0.05	R		1	M	*? ; *9.5, P 240° Δ 3'.2
386	3 41.1	18 59	14.7	0.5	lE 30°	sbMN	1	L	
387	3 42	18 35	13.0	0.3	R		1	L	○ ; neb?
388	3 46.7	9 11	15.0	0 3	R		1	M	*9, P 185° Δ 4'.2
389	3 47.9	9 20	15.0	0.8×0.2	E 180°		1	M	*9.5, p 20^s s 2'
390	3 48.8	— 8 27	15.3	0.1	R		1	L	*14, np 4'
391	3 49.1	—10 32	16.0	0.6×0.1			1	M	1st of 2 ; neb**, P 170°
392	3 49.3	10 35	15.5	0.4	iR		1	M	2d of 2 ; *10, f 30^s
393	3 52.1	22 8	15.8	0.2	R		1	L	
394	3 53.4	19 32	15.0	1.0×0.6	E 190°		1	M	
395	4 20.7	10 21	13.5	1.0	R		1	M	*9.5, P 185° Δ 2'
396	4 27.3	4 49	15.5	0.2	R	bMN	1	L	
397	4 31.8	5 13	15.0	0.2	R		1	L	*8, np 12^s
398	4 33.1	19 8	16.0	0.1	R		1	L	
399	4 33.9	9 40	15.0	0.2	R		1	M	
400	5 17.1	—23 56	14.0	3.0×1.8	E 240°		1	M	*8, P 245° Δ 0'.6
401	8 15.6	— 8 37	15.8	1.0			1	S	rr ; *7.5, P 50° Δ 5'
402	8 18.6	4 37	13.5	0.4	R	sbMN	1	M	1st of 4
403	8 18.8	4 36	14.0	0.5	R		1	M	2d of 4
404	8 18.9	4 33	14.0	0.5	R		1	M	3d of 4
405	8 19.0	4 35	16.2	0.8	R		1	M	4th of 4 ; neb?
406	8 37.7	3 13	12.0	0.7×0.3	E 50°	gbM stell N	1	S	*9, P 240° Δ 0'.8
407	8 41.0	18 55	11.0	0.6	R	gbMN	1	M	
408	9 0.1	18 39	15.0	0.4	R		1	M	1st of 3
409	9 0.5	18 36	15.0				1	M	2d of 3 ; *?
410	9 0.6	—18 36	15.2	0.5×0.4	E 180°		1	M	3d of 3
411	9 19	— 9 57	15.3	0.4	R		1	M	10^s p (412) ; α 9^h 24^m?
412	9 19	9 57	14.5	1.2×0.6	E 170°	gbM	1	M	bet 2 st 12 and 14
413	9 20:	6 15	13.5	0.4		gbM	1	S	
414	9 34	9 39	15.5	0.6	iR	sbM	1	M	*9.5, f 30^s
415	9 34.2	18 40	12.0	0.4	R		1	M	*9.5, P 130° Δ 3'.8
416	9 43.8	2 21	15.0	0.2			1	S	*11, P 300° Δ 3'
417	9 45.0	11 44	15.7	0.2	R	gbsbMN	1	L	
418	9 49	9 52	14.0	0.6	vlE 200°	gbMN	1	M	
419	10 3.1	11 27	16.2	0.2	R		1	L	
420	10 4	—11 24	16.0	0.1	R		1	L	1st of 2
421	10 4	—11 16	15.6	0.1	R		1	L	2d of 2
422	10 29.4	16 42	15.7	0.4	lE 180°	gbM	1	L	*7.5, n 6'
423	10 32.8	11 5	15.7	1.0	vE 160°		1	L	*np end
424	10 34.5	—23 15	14.0	0.8	vlE 180°		1	M	

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No.	R.A. 1890.0	Decl. 1890.0	Mag.	Size	Form	Condensation	No. of Obs.	Obsv'r	Notes
	h m	° ′							
425	10 35.0	—23 20	13.5	0.4	iR	gbM	1	M	
426	10 44.9	16 27	16.0	0.3	E 200°	sb*	1	L	2 vF st inv in eF neb
427	10 45.4	16 38	15.4	0.2	R	pgbMN	2	L	*8.5, s 6′
428	10 45.9	16 26	15.0	0.6×0.2	E 130°	gbsbMN	1	L	
429	10 49.0	16 26	14.0	1.0×0.3		gbsbMN	1	L	
430	10 53.7	— 6 58	15.5	0.3			1	S	rr; prob vF Cl; *9, P 120° Δ 5′
431	11 0.1	—17 21	15.3	0.4	iR	gpmbM	1	L	sev vF st inv
432	11 4.0	12 48	12.0				1	M	neb*; *12, P 40° Δ 2′.1
433	11 14.8	8 24	15.5	0.1	R	bMN	1	L	D; P 85° Δ 0′.4; *12, p 3ˢ
434	11 14.8	8 24	15.5	0.1	R	bMN	1	L	
435	11 15.2	7 30	15.8	0.4			1	S	2 st 10 f
436	11 20	10 1	15.0	0.2	R		1	M	*10, nf; * 10, sf
437	11 22.2	8 33	16.0	0.1	lE 0°	gbM	1	L	
438	11 23.0	10 51	15.6	0.1	R	bMN	1	L	
439	11 23.6	8 23	15.2	0.1	R	glbM	1	L	*10, p 30ˢ; *10, f 30ˢ
440	11 25.4	—10 28	16.0	0.2	R?		1	L	*9, s 4′
441	11 27.0	— 8 51	15.5	0.1	R	gbM	1	L	
442	11 27.0	9 4	15.2	0.2	R	sbMN	1	L	1st of 2
443	11 27.2	9 6	15.0	0.4	R	sbMN	1	L	2d of 2
444	11 27.3	13 16	15.2	0.1	R	gbMN	1	L	*11, sf 1′
445	11 27.8	9 0	15.6	0.5	lE 140°	glbuM	1	L	
446	11 31.8	8 44	14.5	0.1	R		1	L	*10, p 15ˢ
447	11 32.8	8 21	15.8	0.2×0.1	E 75°		1	L	another neb or eF* p 0′.5; *9 np 3′
448	11 34	8 59	14.8	0.3×0.2	E 180°	gbM	1	L	
449	11 38.8	8 46	14.5	0.3	lE 70°	gbsbMN	1	L	
450	11 39.1	— 8 41	15.6	0.1	R	gbM	1	L	*9.5, p 3ˢ
451	11 47.2	—10 49	16.0	0.8×0.5	E 160°	gvlbM	1	L	
452	11 49.5	10 16	16.0	0.1	R	bMN	1	L	*9.5, np 4′
453	11 49.8	18 8	15.0	0.2		gbMN	1	S	*10, P 340° Δ 4′
454	12 7	8 32	16.0	0.3	R	slbMN	1	L	*10, f 15ˢ
455	12 9.5	10 58	15.5	0.1	R	bMN	1	L	
456	12 41.0	3 59	15.5	0.1	R		1	L	neb?; * f 2ˢ
457	12 56.1	3 55	15.7	0.1	R	bMN	1	L	G.C. 3366 sp 4′
458	13 9.0	3 36	15.5	0.2	R	gbM	1	L	1st of 2
459	13 9.2	3 35	15.8	0.1	E 45°		1	L	2d of 2
460	21 5	—23 32	15.5	0.5	iR		1	M	
461	21 34.5	—22 58	14.0	0.3	R	gbM	1	M	1st of 2
462	21 34.5	22 56	14.3	0.2	iR	gbMN	1	M	2d of 2
463	21 43	12 18	16.0	vS	R		1	M	neb?; *9.5, P 95° Δ 2′
464	21 51	—12 7	14.0				1	M	neb*; *9.5, P 40° Δ 2′.8
465	21 53	+ 0 54	15.7		R		1	L	4 vF st from 1′ to 4′ n
466	22 4.5	—23 32	15.5	0.2	vlE	gbM	1	M	*10, P 5° Δ 3′.2
467	22 16	22 17	13.0	0.4	R		1	M	*11, P 280° Δ 4′.5
468	22 22.5	22 42	15.0	0.1	E 330°		1	M	slightly nebulous**
469	22 35.5	23 28	15.0	0.3×0.1	E 175°	biN, bn	1	M	D
470	22 58.0	—23 30	15.8	0.2	lE 85°	sbM	1	M	3 st 10, p 20ˢ
471	23 5	—22 21	15.8	0.3	E 290°		1	M	**?
472	23 8	23 29	16.0	0.3	iR	sbM?	1	M	*10, P 75° Δ 3′.2
473	23 11.5	22 46	15.8	0.7	iR	bnp	1	M	*10, P 290° Δ 4′.4
474	23 18	12 36	14.5	0.2×0.1	E 260°		1	M	neb?; *9, P 10° Δ 3′.6
475	23 43.2	22 39	15.5	0.3	iR	sbM	1	M	**10, nf 50ˢ
476	23 57.6	—12 36	15.2	0.5×0.2	E 80°		2	M	*8.5, f 38ˢ; *9, np 40ˢ

S = Ormond Stone; L = F. P. Leavenworth; M = Frank Muller.

After our copy had gone to press, no. 6 of our last list was found to be identical with nebula no. 2, catalogue no. 4, of nebulas discovered at the Warner Observatory (A.N. 2752). No. 146 was also found to be G.C. 998. Its right-

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ascension in the General Catalogue is probably 2ᵐ too small, that given in the note as brought up from C.H. being right.

University of Virginia, 1887 *January* 26.

The right-ascension of nos. 89–93 should be $2^h\ 58^m$ instead of $3^h\ 1^m$.

RING-MICROMETER OBSERVATIONS OF COMET 1886 *e* (*FINLAY*)

MADE AT THE LEHIGH UNIVERSITY OBSERVATORY

By C. L. DOOLITTLE.

1887	Greenwich M.T.	✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Jan. 25	13 35 24.1	*s*	5	+4 20.02	− 2 28.9	1 42 40.38	+12 13 14.9	9.462	0.667
26	12 34 25.2	*t*	6	+0 43.33	−14 32.9	1 46 37.12	+12 37 23.8	9.323	0.639

Mean Places for 1886.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
s	1 38 17.53	+2.83	+12 15 30.9	12.9	W. Bessel I 668
t	1 45 50.91	+2.88	12 51 44.2	12.6	W. Bessel I 786

FILAR-MICROMETER OBSERVATIONS OF COMETS 1887 *b* (*BROOKS*) AND 1887 *c* (*BARNARD*)

MADE AT THE DUDLEY OBSERVATORY, ALBANY.

1887 Albany M.T.	✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs'r
			COMET 1887 *b*						
h m s			m s	′ ″	h m s	° ′ ″			
Jan. 24 14 22 49	*a*	21 , 7	+ 5 14.36	+3 5.1	18 23 26.17	+73 53 30.9	*n*0.149	0.642	B
26 15 50 43	*b*	15 , 5	− 8 1.90	+2 11.3	18 49 14.90	+75 40 19.9	*n*0.240	0.377	B
27 11 5 37	*c*	3 , 1	−12 6.33	−2 21.6	19 1 7.41	+76 19 56.8	*n*9.782	0.885	B
29 10 53 45	*d*	15 , 5	− 1 54.54	+2 36.4	19 36 27.53	+77 50 45.0	8.763	0.882	B
Feb. 9 8 34 22	*e*	12 , 4	− 8 3.50	−5 59.7	0 32 33.80	+77 45 16.0	0.305	9.275	B
			COMET 1887 *c*						
Jan. 24 18 4 12	1	7 , 7	+ 1 19.09	−3 2.4	19 10 19.99	+25 58 14.3	*n*9.662	0.652	E
26 18 7 13	2	9 , 3	− 6 9.53	+3 26.8	19 15 45.14	+27 12 13.1	*n*9.330	0.635	B

Adopted Mean Places for 1887.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
a	18 18 15.74	−3.93	+73 50 28.1	− 2.3	DM. 73°,817; Bonn VI.
b	18 57 21.12	−4.32	75 38 9.1	− 0.5	Radcliffe and Kasan, A.G. Zones
c	19 13 18.24	−4.50	76 22 18.2	+ 0.2	Greenwich Nine-Year Catalogue
d	19 38 26.93	−4.86	77 48 7.4	+ 1.2	Kasan, A.G. Zones
e	0 40 38.96	−1.66	77 51 4.4	+11.3	Fed. 116 (½ Wt.) and Oe. Argel. 720
1	19 9 2.44	−1.54	26 1 16.0	+ 0.7	W. Bessel, 19^h,216
2	19 21 56.20	−1.53	+27 8 45.9	+ 0.4	W. Bessel 624 and comp. with ditto 625

The observation marked E was made by Mr. H. V. Egbert; those marked B by Prof. Boss.

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EXCHANGE OF LONGITUDE-SIGNALS BETWEEN ST. LOUIS AND MEXICO.

The longitude of the National Observatory of Mexico has recently been determined by a direct exchange of clock-signals with this Observatory. The *Observatorio Nacional*, formerly at Chapultepec, is now at Tacubaya, about six miles from the city of Mexico. The outfit of the Observatory includes an equatorial of 15 inches aperture, by GRUBB, and a meridian-circle of 8 inches aperture, by TROUGHTON & SIMMS, almost a duplicate of the Harvard College instrument.

The time-observations at Tacubaya were made by Sr. ANGUIANO, Director of the Observatory, with a large TROUGHTON & SIMMS Altazimuth of 3 inches aperture, used as a transit-instrument. At St. Louis, the time-observations were made by myself with a 3-inch FAUTH Transit. At each station the clock-correction was determined on each night for two epochs, one before and one after the time of exchange. The probable error of the clock-correction on any night was about $\pm 0^s.01$ at each station. From comparisons made at the city of Mexico in August, 1885, about the middle of the series, a personal equation between Sr. ANGUIANO and myself was found, amounting to $+0^s.139$ taken in the sense P—A, and this value has been used in the results given below.

The circuit was 2580 miles in length, and contained seven repeaters. The individual results are as follows:

1885	$\Delta\lambda$ by Signals. St. Louis to Tac.	$\Delta\lambda$ by Signals. Tac. to St. Louis.	Mean.	Armature Time.
May 15	$35^m 57^s.125$	$35^m 57^s.852$	$35^m 57^s.488$	0.363
June 2	57.076	57.791	57.433	0.357
Nov. 25	57.116	57.759	57.437	0.321
Dec. 3	57.003	57.587	57.295	0.292
Dec. 23	57.084	57.725	57.404	0.320

Tacubaya west of St. Louis	$0^h\ 35^m\ 57^s.41 \pm 0^s.02$
St. Louis west of Greenwich	$6\ \ 0\ \ 49.16 \pm 0.01$
Tacubaya west of Greenwich	$6\ \ 36\ \ 46.57 \pm 0.02$

To this should be applied the correction, $-0^s.03$, to reduce it to the pier of the large meridian-circle; giving, as a final value of the longitude, $6^h\ 36^m\ 46^s.54$. The value heretofore in use, derived from moon-culminations, was $6^h\ 36^m\ 41^s.6$, nearly 5^s in error.

H. S. PRITCHETT.

OBSERVATIONS OF COMETS

MADE WITH THE 9.6 INCH EQUATORIAL AT THE U.S. NAVAL OBSERVATORY

BY PROF. E. FRISBY.

(Communicated by the Superintendent.)

Washington M.T. 1886–1887	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			COMET 1886 *e* (*FINLAY.*)					
Dec. 16 $8^h\ 8^m\ 36^s.7$	1	20 , 4	$-0^m\ 35^s.07$	$-\ 2'\ 19''.7$	$22^h\ 32^m\ 55^s.04$	$-10°\ 12'\ 54''.5$	9.551	0.795
20 7 8 50.4	2	20 , 4	—1 26.33	— 3 4.8	22 53 18.48	— 7 51 41.1	9.401	0.887
21 6 13 31.3	3	20 , 4	—0 15.62	+ 0 51.1	22 58 14.49	— 7 17 3.4	9.184	0.800
Jan. 10 6 57 21.1	4	10 , 2	—2 58.65	— 0 53.3	0 36 47.00	+ 4 45 57.5	9.295	0.698
12 7 47 50.5	5	19 , 4	—0 40.21	—10 5.9	0 46 8.90	+ 5 52 53.2	9.450	0.693
18 7 11 38.9	6	20 , 4	—1 38.54	+ 3 1.8	1 12 48.89	+ 8 58 50.0	9.339	0.654
22 7 41 51.3	7	15 , 3	—4 50.63	+10 3.9	1 30 4.96	+10 53 9.2	9.429	0.649
			COMET 1887 *b* (*BROOKS.*)					
Jan. 24 10 28 17.7	8	20 , 4	+3 34.68	— 4 57.6	18 21 47.00	+73 45 28.2	*n*9.220	0.910
25 10 27 14.5	9	15 , 3	—0 44.02	+ 6 53.7	18 33 11.07	+74 37 45.5	*n*9.041	0.909
			COMET 1887 *c* (*BARNARD.*)					
Jan. 31 17 34 20.4	10	20 , 4	—1 29.45	+ 9 41.4	19 28 39.55	+30 18 7.7	*n*9.715	0.602

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Adopted Mean Places for 1886.0 and 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	22 33 28.12	+1.99	−10 10 50.0	+15.2	WB. XXII. 672
2	22 54 42.76	+2.05	− 7 48 51.4	+15.1	SDM. −7°, 5907
3	22 58 28.05	+2.06	− 7 18 9.7	+15.2	⅓(Weisse + 2 Schj.)
4	0 39 46.20	−0.55	+ 4 46 55.9	− 5.1	WB. O. 655
5	0 46 49.64	−0.53	+ 6 3 4.1	− 5.0	WB. O. 787
6	1 14 27.94	−0.51	+ 8 55 53.7	− 5.5	WB. I. 193
7	1 34 55.94	−0.35	+10 43 11.1	− 5.8	WB. I. 587
8	18 18 15.75	−3.43	+73 50 28.1	− 2.3	Bonn VI. +73°, 817
9	18 33 58.93	−3.84	+74 30 53.1	− 1.3	O. Arg. N. 18492
10	19 31 10.50	−1.50	+30 8 27.1	− 0.8	Leiden Zones 67,80 and 69,81

The position of SDM. −7°, 5907 was obtained, 1887 January 12 and 15, by comparing it with WB. XXII. 1203 = Schj. 9475, giving double weight to Schjellerup.

The position of Brooks's comet, January 25, was telegraphed 20″ wrong; this position is right.

RING-MICROMETER OBSERVATIONS OF COMETS

MADE AT THE VANDERBILT UNIVERSITY OBSERVATORY

BY E. E. BARNARD.

1887	Nashville M.T.	No. Comp.	$\Delta\alpha$	$\Delta\delta$	* Comparison-Star.
			COMET 1887 *b* (*BROOKS.*)		
Jan. 23	14ʰ 29ᵐ 47ˢ	8	+1ᵐ 24ˢ.88	− 0′ 45″.3	18ʰ 12ᵐ 9ˢ +73° 2′.5 (Eq. pointings)
			COMET 1887 *c* (*BARNARD.*)		
Jan. 23	17 36 47	9	−1 31.03	−11 53.6	DM. 25°,3757 = Lal. 36179
26	17 59 11	3	+4 29.40	− 2 7.0	DM. 27 ,3313 = Lal. 36293,4

The comet 1887*c* was discovered at Nashville on the morning of January 24, at about 4ʰ 45ᵐ, with the five-inch refractor, while seeking comets. It was of average size, about 10ᴹ, very slight central condensation, round.

ELEMENTS AND EPHEMERIS OF COMET 1887 *b* (*BROOKS.*)

BY LEWIS BOSS.

The elements of Comet 1887 *b*, here given, are based upon Albany observations of January 24 and 29, and February 9, already reported to the *Journal*.

ELEMENTS.

$$\begin{aligned} T &= 1887 \text{ March } 16.7117 \text{ Greenwich M.T.} \\ \omega &= 158^\circ\ 53'\ 30'' \\ \Omega &= 279\ \ 43\ \ 18 \\ i &= 104\ \ 22\ \ 33 \\ \log q &= 0.21372 \end{aligned} \quad \left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} 1887.0$$

Comparison with the middle place gives (C—O):

$$\Delta\lambda \cos\beta, = -6''; \quad \Delta\beta = -14''$$

Dudley Observatory, 1887 *February* 10.

EPHEMERIS FOR GREENWICH MIDNIGHT.

Date 1887.	α	δ	log Δ	Light
	h m s	° ′		
February 13	1 40 8	+74 4.5	0.1125	1.3
15	2 3 49	71 54.2	0.1143	1.3
17	2 22 40	69 38.7	0.1171	1.3
19	2 38 2	67 19.9	0.1207	1.3
21	2 50 48	65 0.1	0.1252	1.2
25	3 10 54	60 24.0	0 1362	1.2
March 1	3 26 16	55 58.2	0.1498	1.1
5	3 38 37	51 47.4	0.1652	1.1
9	3 48 58	47 53.7	0.1819	1.0
13	3 57 56	44 17.5	0.1995	0.9
17	4 5 52	40 58.6	0.2175	0.8
21	4 13 4	37 56.1	0.2356	0.8

The unit of light is referred to the date of discovery.

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ON THE NEW VARIABLE NEAR ξ_1 ORIONIS.

[illegible]

BY EDWIN F. SAWYER.

[illegible]

... or about 7^{m}.7. The adopted comparison-stars and light-scale are as follows:

		1855.0		Mag.	L
$a =$	DM. 19.1126 $=$	5 44 22.0	+19 43.6	6.3	30.9
$b =$	19.1110 $=$	5 43 48.7	+19 49.4	6.9	25.4
$c =$	20.1156 $=$	5 44 42.3	+20 15.8	7.2	20.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The following are the [illegible] observed [illegible]:

		Light			Light
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	1	5.2:		26	18.6
	3	6.1	1887 Jan.	2	17.8*
	6	7.4*		11	14.9:
	28	4.1:		13	14.9:
Mar.	10	4.1:		16	13.5
Nov.	18	11.2		27	10.2

* = Moonlight.

Cambridgeport, Mass., 1887 January 27.

COMET 1887 c.

The almost unprecedentedly bad weather, which has prevailed during February, has prevented all observation of the comet discovered, January 23, by BARNARD, at Nashville. It seems, therefore, well to transcribe from the circular issued by the *Science Observer*, February 1, the first elements and ephemeris of this comet, computed by Mr. EORERT, at Albany.

The elements were deduced from the observations at Nashville, January 23, and at Albany, January 24 and 26.

$$T = \text{Dec. } 2.0876 \text{ Greenw. M.T.}$$
$$\omega = 35° \; 7'$$
$$\Omega = 258 \; 52$$
$$i = 85 \; 46$$
$$\log. q = 0.17970$$

C—O
$\beta = +0.02$ [illegible]
$= -0.04$ [illegible]

EPHEMERIS [illegible] GREENWICH [illegible]

		α	δ	[illegible]
Feb.	2	19 [illegible]	-31 18	[illegible]
	6	19 [illegible]	33 48	[illegible]
	10	19 [illegible]	[illegible]	[illegible]
	14	20 [illegible]	[illegible]	[illegible]
	18	20 [illegible]	[illegible]	[illegible]
	22	20 [illegible]	[illegible]	[illegible]

Light at discovery [illegible]

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THE

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ON THE SPECTRA OF THE NEW VARIABLE IN *ORION*, OF CERTAIN TEMPORARY STARS, AND OF THE NEBULAS.

BY ORRAY T. SHERMAN.

Shortly after the discovery of the star near χ_1 *Orionis*, it was announced that bright lines formed a portion of its spectrum. The announcement quickly followed that these were simply the effect of contrast. The Dun Echt observers compared its spectrum to that of hydro-carbon. The interpretation was disputed. Amid this discussion it seemed venturesome to launch a series of observations whose interpretation was not evident. Since then, however, we have, instrumentally, studied the spectrum of β *Lyrae* and, historically, that of [illegible] the temporary stars. The result, though conditi[illegible] the inherent inaccuracy of the stellar data, and by [illegible] fullness of one of the comparison-spectra, seems ye[illegible]out value and interest.

[illegible]llowing table are gathered those observations upon [illegible] which have come under my notice. The first col[illegible]he wave-length; the second, the description of the [illegible]ed. The letter appended refers to the observer [illegible]y. The third and fourth columns contain the wave-lengths of the lines in the comparison-spectra to which the stellar spectra have reference. The intensities are appended. No weight is attached to the identification of the WOLF and RAYET lines, other than to show that they are amenable to the same explanation as the spectra observed by HUGGINS, or STONE and CARPENTER. HUGGINS observed on May 15 and 17, and gives us C, F, 434?, 471, 467. STONE and CARPENTER observed on May 20, 22, 23, 24, 25, and June 7, and gives us 502, F, 467, 463. WOLF and RAYET observed upon May 20. During HUGGINS's observations the star was of the 3.6 to 4.9 magnitudes. On WOLF and RAYET's of the 6th, and during the period covered by STONE and CARPENTER, from 6^m.2 to the 9th magnitude. The change in the spectrum during the interval was apparently toward a diminution of the electrical excitation of the hydrogen, lagging slightly behind the dimming of the interior light. A similar change is found in the bright-line stars.

T Coronae.

λ		Remarks	Hydrogen λ	Hydrogen i	Oxygen λ	Oxygen i
C	a		C			
			5887.87	6		
			5883.52	6		
		Assez brillante, semble correspondre à D (b)	5878.08	4		
			5871.38	4		
			5868.76	4		
		Une ligne brillante, mais faible (b)	5812.00	6		
			5504.50	4		
		Une bande brillante, à la limite à peu près du jaune et du vert. (b)	5498.45	4		
			5494.79	3		
			5480.04	4		
			5015.87	4		
502	c		5014.13	4		
			5012.21	4–5		

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ON THE NEW VARIABLE NEAR χ_1 ORIONIS.

$5^h\ 47^m\ 13^s$, $+20°\ 8'.8$ (1855.0).

By EDWIN F. SAWYER.

The first opportunity of observing this variable (the so called Nova), after its announced discovery by GORE, was on the evening of December 19, 1885, in strong moonlight. It was found to be =DM. 19°,1110, and 5+ steps < DM. 19°,1126, or about $6^M.4$. At the next observation, December 24, it was observed to be somewhat fainter, showing that it had passed its maximum. The observations were continued until March 10, 1886, on which date the star was ½ step > DM. 20°,1168, and 4 steps < DM. 20°,1171, or $8^M.6$. The variable was again looked for on November 18, 1886, and found to be 3 or 4 steps < DM. 19°,1106, or about $7^M.2$. The increase of light from this date appeared quite rapid and uniform. A maximum was passed on December 13, 1886, the greatest brightness being 2 steps > DM. 20°,1156, and 3 steps < DM. 19°,1110, or $6^M.6$, which was somewhat fainter than last year. The star is now, 1887 January 27, 5+ steps < DM. 19°,1106, and 2 or 3 steps > DM. 20°,1171, or about $7^M.7$. The adopted comparison-stars and light-scale are as follows:

		1855.0 (α)	1855.0 (δ)	Mag.	L
a =	DM. 19°,1126 =	$5^h\ 46^m\ 22^s.0$	$+19°\ 43'.6$	6.3	30.9
b =	19,1110 =	5 43 48.7	+19 49.4	6.0	25.4
c =	20,1156 =	5 44 42.3	+20 15.8	7.2	20.0
d =	DM. 19°,1106 =	$5^h\ 43^m\ 18^s.7$	$+19°\ 28'.6$	6.8	14.7
e =	20,1171 =	5 47 0.1	+20 26.2	8.2	8.7
f =	20,1168 =	5 46 36.6	+20 25.5	8.6	3.1

Cambridgeport, Mass., 1887 *January* 27.

The following are the light-values observed on each evening:

		Light			Light
1885 Dec.	19	25.4*	1886 Nov.	21	15.3
	24	22.4		24	16.8
	28	21.2		26	17.3
	29	20.4		27	17.3
	30	20.4		28	20.2
1886 Jan.	1	19.7	Dec.	1	20.2*
	5	17.8		8	21.2*
	6	17.6		14	22.2
	7	17.1		16	22.2
	10	17.1*		20	22.2
	12	17.1*		21	22.2
	13	16.6*		25	20.2
	23	11.0		27	18.6
Feb.	1	9.2:		28	18.6
	5	8.1	1887 Jan.	2	17.8*
	8	7.4*		11	14.9:
	28	4.1:		13	14.9:
Mar.	10	4.1:		16	13.5
Nov.	18	11.2		27	10.2

* = Moonlight.

COMET 1887 *c*.

The almost unprecedentedly bad weather, which has prevailed during February, has prevented all observation of the comet discovered, January 23, by BARNARD, at Nashville. It seems, therefore, well to transcribe from the circular issued by the *Science Observer*, February 1, the first elements and ephemeris of this comet, computed by Mr. EGBERT, at Albany.

The elements were deduced from the observations at Nashville, January 23, and at Albany, January 24 and 26.

$$\begin{aligned} T &= \text{Dec. } 2.0876 \text{ Greenw. M.T.} \\ \omega &= 35°\ 7' \\ \Omega &= 258\ \ 52 \\ i &= 85\ \ 46 \\ \log. q &= 0.17970 \end{aligned}$$

C—O

$$\begin{aligned} \Delta\lambda \cos\beta &= +0'.02 \\ \Delta\beta &= -0\ .04 \end{aligned}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1887		α	δ	log Δ	Light
Feb.	2	$19^h\ 34^m$	$+31°\ 18'$	0.3327	0.94
	6	19 46	33 48	0.3330	0.91
	10	19 58	36 18	0.3340	0.88
	14	20 11	38 47	0.3360	0.84
	18	20 24	41 14	0.3388	0.81
	22	20 38	+43 38	0.3424	0.77

Light at discovery taken as unity.

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ON THE SPECTRA OF THE NEW VARIABLE IN *ORION*, OF CERTAIN TEMPORARY STARS, AND OF THE NEBULAS.

By ORRAY T. SHERMAN.

Shortly after the discovery of the star near χ_1 *Orionis*, it was announced that bright lines formed a portion of its spectrum. The announcement quickly followed that these were simply the effect of contrast. The Dun Echt observers compared its spectrum to that of hydro-carbon. The interpretation was disputed. Amid this discussion it seemed venturesome to launch a series of observations whose interpretation was not evident. Since then, however, we have, instrumentally, studied the spectrum of β *Lyrae* and, historically, that of certain of the temporary stars. The result, though conditioned by the inherent inaccuracy of the stellar data, and by the over-fullness of one of the comparison-spectra, seems yet not without value and interest.

In the following table are gathered those observations upon *T Coronae* which have come under my notice. The first column gives the wave-length; the second, the description of the line observed. The letter appended refers to the observer or authority. The third and fourth columns contain the wave-lengths of the lines in the comparison-spectra to which the stellar spectra have reference. The intensities are appended. No weight is attached to the identification of the Wolf and Rayet lines, other than to show that they are amenable to the same explanation as the spectra observed by Huggins, or Stone and Carpenter. Huggins observed on May 15 and 17, and gives us C, F, 434?, 471, 467. Stone and Carpenter observed on May 20, 22, 23, 24, 28, and June 7, and gives us 502, F, 467, 463. Wolf and Rayet observed upon May 20. During Huggins's observations the star was of the 3.6 to 4.9 magnitudes. On Wolf and Rayet's of the 6th, and during the period covered by Stone and Carpenter, from $6^{M}.2$ to the 9th magnitude. The change in the spectrum during the interval was apparently toward a diminution of the electrical excitation of the hydrogen, lagging slightly behind the dimming of the interior light. A similar change is found in the bright-line stars.

T Coronae

λ		Remarks	Hydrogen λ	Hydrogen i	Oxygen λ	Oxygen i
C	*a*		*c*			
			5887.87	6		
			5883.52	6		
		Assez brillante, semble correspondre à D (*b*)	5878.08	4		
			5871.38	4		
			5868.76	4		
		Une ligne brillante, mais faible (*b*)	5812.00	6		
			5504.50	4		
		Une bande brillante, à la limite à peu près du jaune et du vert. (*b*)	5498.45	4		
			5494.79	3		
			5480.04	4		
			5015.87	4		
502	*c*		5014.13	4		
			5012.21	4–5		

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λ		Remarks	Hydrogen λ	Hydrogen i	Oxygen λ	Oxygen i
486	abc	The most brilliant; narrow and sharply defined, a The second in brilliancy, b	F			
471±	a	rather over ½ distance from F to G	4722.33 4718.33	3 4	470.90 470.46 469.85	6 10 8
467	ac	double or undefined at the edge	4683.00 4681.66 4679.60	3 2 2	467.54 466.07	8 8
463	c		4633.10 4630.68 4626.86	4 4 3–9	464.80 464.06 463.74	12 7 6
434	?a	Near G; seen by glimpses	434?		436.62 435.35 434.90 434.69	4 5 6 5

The description, coupled with the intensities, refers the lines 471 and 467 to oxygen rather than to hydrogen, while 463 and 434 are very likely due to both.

We pass to *Nova Andromedae*. Two observers detected bright lines.

Nova Andromedae.

λ		Remarks	Hydrogen	Oxygen
557.5	δ e	Center of maximum of the oxygen negative glow	557.2	558.1
548.2	d	Perhaps traced over nucleus of nebula Mean between 545.7 and 550.8	549.9 549.2 549.0 548.8 548.6 548.3 547.6	
532.1	δ e	From time to time other bright lines in this region were also suspected (d)	532.8 532.6 532.1 532.0	532.9
486.	e	Apparently to the whole nebula	F	

It will be noticed that both observers suspected one of the lines referable to hydrogen to belong to the nebula.

We pass next to *Nova Cygni*. Upon this star we have fortunately a large number of observers, and the tabulation at different dates allows us to show how, in the decline of the star, certain lines appeared at certain stages, though unseen before and after. It is to be regretted that wave-length giving observations are not more continuous.

a. Huggins. *Proc. Royal Society*, Vol. 15, 1866.
b. Wolf and Rayet. *Comptes Rendus*, T. LXII.
c. Stone and Carpenter. *Monthly Notices*, Vol. XXVI.
d. Maunder. *Monthly Notices*, Vol. XLVI.
e. Sherman. *American Journal of Science*, Vol. XXX., 1885.

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Nova Cygni.

λ	December 2–5	December 5–8	January 2, 8, 9	January 7, 8	January 18	January 27, Feb. 13	Sept. 3	Oct. 10	Dec. 6	Accept'd values
							A band: upper edge at 500.9, lower edge at 493.9. Maximum at 499.5.	As separate lines		
						676.1				676.1
	661.	656.	656.2	656.1						656.1
			594.?							594.?
	588.	588.	589.5	589.						588.5
583.1										583.1
			579.5	580.	580.4	579.4				579.8
			575.9			574.5				574.7
563.										563.
532.4	531.									531.7
		526.5								526.5
519.7										519.7
	517.			517.						517.
		512.7								512.7
		507.5								507.5
502.1			503.5				500.9			502.8
	500.		500.7	500.0	499.7	501.3	499.5	499.4	502.0	500.3
		498.0								498.0
495.3							493.9	492.2		493.8
								491.2		491.2
485.8	483.	485.8	486.7	486.1	486.1	486.1				485.6
		474.								474.
		470.								470.
466.9			465.0		466.6					466.2
459.0			461.5			461.5				460.1
	451.									451.
436.7	435.	434.?			434.7	437.6				436.0
			414.?							414.?
1	2	3	4	5	6	7	8	9	10	

1 and 10. BACKHOUSE, *Monthly Notices*, Vol. 39. The observations are not separated.

2. CORNU, *Comptes Rendus*, 83. 5. SECCHI, *Astr. Nachr.*, no. 2116.

3 and 6. VOGEL, *Monatsbericht*. Berlin, 1877 and 1878.

4, 7, 8, 9. COPELAND and LOHSE, *Copernicus*, Vol. II. The two observations marked with an interrogation, though given in *Astronomische Nachrichten*, 2117, are not given in the observer's later summary.

Bright Lines in *Nova Cygni.*

λ	Remarks	Hydrogen	Oxygen	λ	Remarks	Hydrogen	Oxygen
676.1	"a mere reddish glow." Feb. 13	677.0 675.12		594.	Probably a faint band	594.91 594.68 593.79 593.07	
656.1	*C.* The brightest line in the spectrum on Dec. 3–5 was, on Jan. 8, already very difficult to see. On Jan. 16 it was "*nicht mehr zu sehen,*" also on Feb. 17	*C*		588.5	Very narrow line	588.78 588.35	

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λ	Remarks	Hydrogen	Oxygen
583.1		583.54 583.23 583.05	
579.8	Not observed in December. Jan. 2, very bright band. Jan. 9, very narrow line. Feb. 13, excessively faint	581.28 580.68 580.56 580.40 580.05 579.43 579.42 579.13 579.08	
563.		564.15 563.34 562.93 562.58	
531.7	Dec. 5, very bright, probably seen also in *Nova Andromedae*	532.84 532.48 532.05 531.99 531.58 531.10 530.97	
526.5	Dec. 5–8 only, a band from 528–526	529.08 528.26 527.20 526.58 526.37	
507.5	Dec. 5–8, only 507–509	508.45 508.10 507.98 507.49 507.18 506.95 506.74 506.33	
502.8	Jan. 2–9	505.42 504.09 503.89 502.96 501.41 501.22 500.75 500.27	
500.33	Faint in December, growing in brilliancy till it overpowers and remains after all other lines in the spectrum	500.93 500.86 500.43 499.90 499.12	
498.20	In December a band from 407–409. Later a portion of the preceding band	498.43 498.17 498.05 497.97 497.75 497.46	
493.67	A line or as the edge of above band	493.61 493.51 492.94 492.92	494.22 494.02
491.2		491.30 491.29	492.37 490.65
486.		F	485.62
470.	Band 469–470	470.71 470.54	470.90 470.46 469.85
466.2	Faint band 463–467	463.53 463.32	467.54 466.07 464.93 464.80 464.06 463.74
460.3	Faint line	461.75	459.51 458.99
451.3		449.7	
436.0		434.0	436.62 435.35 434.90 434.69
414.?		415.2?	

And also the following lines, which appear to indicate the presence of carbon, although it is not necessary to presume that such is the case. Probably they are due to both oxygen, hydrogen and their carbon compounds.

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λ	Remarks	Oxygen	Hydrogen	Carbon Compounds
519.7	Probably not seen after Jan. 2	520.59	519.89 519.59	519.7
517.0	Bright band in December, not seen after Jan. 8	515.93	517.77 517.23 517.09 516.68 516.43 516.38 515.95	516.39
512.7	Not seen after Dec. 8		513.48 513.24 512.55	512.84
474.	Not seen after Dec. 8		474.05	473.73
470.	Not seen after Dec. 8	as above		469.84

We pass next to the star near χ_1 *Orionis*, remarking only that it gives us pleasure to recognize the traces of an atmosphere as at least a cooperator in the change in brightness of this variable.(1) A similar case is found in β *Lyrae*.(2)

We tabulate as before, first the observed lines. In the Dun Echt and New Haven series the number of days upon which the line in question was observed is also given. The Dun Echt series represents three days of observation, the New Haven series, nine.

(2) *American Journal of Science*, February, 1887.
(1) *Astronomische Nachrichten*, Nos. 2756, 2755.

Copeland		Konkoly	Von Gothard	Sherman		Mean	Remarks
λ	Days	λ	λ	λ	Days		
				652.3	4	652.3	
				632.9	1	632.9	
				614.6	6	614.6	
				601.7	2	601.7	
				594.9	1	594.9	*Nova Cygni* 594.
		587.5		587.5	7	587.5?	*Nova Cygni* 588.5
584.1	1				5	584.1?	*Nova Cygni* 583.1
				571.4		571.4	
				560.9	8	560.9?	
				545.3	7	545.3?	*Lalande* 13412
				531.6	8	531.6?	*Nova Cygni* 531.7
				519.4	6	519.4	*Nova Cygni* 519.7
516.2	3				4	516.2	*Nova Cygni* 517.
513.7	1		510.	512.8		512.2	*Nova Cygni* 512.7
				504.8	4	504.8	
				498.0	5	498.0	*Nova Cygni* 498.0
494.4	3					494.4?	
492.3	1		490.			491.1	*Nova Cygni* 491.2

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Copeland		Konkoly	Von Gothard	Sherman		Mean	Remarks
λ	Days	λ	λ	λ	Days		
477.8	2	F+		487.7 477.3	5 4	487.7 477.5	
472.2	2			470.6 462.4	7 5	471.4? 462.4	*T Coronae* 471 *T Coronae* 463
456.2	1			456.2 448.0	4 6	456.2 448.0	
				438.6 433.3	5 2	438.6 433.3	
				428.6 421.9	2 2	428.6 421.9	
				414.6	1	414.6	*Nova Cygni* 414.

In proceeding, we limit ourselves to suggesting the interpretation of those lines which have not probably been already dealt with in discussing the former spectra. In certain cases the number in the frequency column is so high or so low that, on account of the short series of observation, we hold their character as bright lines still open to question, and if admitting them into the following list it is only to show the possible identification.

λ	Remarks	Nitrogen	Hydrogen	Oxygen
652.3	Probably one or more of		653.53 653.03 652.15 651.62	
614.6			614.4	
601.7			602.04 601.74	
571.4			571.57 571.04	
504.8	Band probably one or more of		506.79 506.33 505.42 503.89 502.96	
494.4			493.51	494.2
487.7			487.52 487.24	
477.6	Fairly bright, Dec. 17; just discernible Dec. 26	478.66 477.61		
456.2			457.03	
448.0	A band		449.75 448.97 447.37 446.66 446.06	446.92 446.53
438.6			439.0	
433.3			434.0	
428.6		428.0		
421.9			422.0	

We pass at once to the spectrum of the nebulas. D'ARREST's values of the three prominent lines are taken as the sum of observation thereon up to 1872.

λ	Remarks	Hydrogen
554.	a trace*	554.22 553.64
527.	a trace*	527.20 526.57 526.36
518.	a trace	517.77
509.	a trace	508.75 508.54 508.46 508.40 508.37
500.42	D'Arrest, 500.40 Bredichin, 500.44 *Nova Cygni*, 500.33	500.43
495.70	D'Arrest, 495.66 Bredichin, 495.74	495.68
485.99	D'Arrest, 486.06 Bredichin, 485.92	486.06
479.	a trace	479.68
434.	Photographs	434.0
410.1	Draper's Photograph	410.1
373.0	Photograph ; the white star line	373.3

We think, therefore, that, so far as the data as yet obtained permit us to judge, the spectra of those variable or tem-

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porary stars which have as yet been examined, the spectra of the bright-line stars** and the spectra of the nebulas may all be explained by reference to the low-temperature spectrum of hydrogen, the high-temperature spectrum of nitrogen and oxygen, or their carbon compounds. A recent investigator in studying the spectrum of the atmosphere of β *Lyrae*† finds, in addition to the above-named spectra, traces of oxygen at the negative pole and nitrogen at the negative pole; and infers a connection between these spectra and the variation of the star's light. He finds reason to think that a portion of the light of that star is produced by a low electric discharge in its atmosphere, the charge being the residual of that produced by chemical reaction in the interior; hydrogen acting as the positive pole, while some one of the elements higher in the electrolytic series acts as the negative pole. Under this discharge he finds the carbon-compounds forming, being dissociated, re-forming. Was it in the days of the carboniferous era that, other causes operating, the terrestrial atmosphere went through a similar purification? Is it to our sun's nebulous atmosphere that the A and B bands of our solar spectrum are due? Is the zodiacal light an inner or an outer layer of the same nebulous atmosphere? What have comets to tell us of the extent of the hydrogen-atmosphere? What is the motion that changes in this current impart to the terrestrial magnetic needle? But it is needless to recall to the student of terrestrial and cosmical physics the points of contact of the phenomenon in question.

If we are right in the above analysis, and if we have not erred in our former paper, then, from the most gaseous nebula, on through the nebulas showing continuous and bright line spectra, on through the gaseous stars, through the variable stars to the most highly finished orb we know, with the temporary stars passing through and binding the whole series —through all we have one phenomenon, waxing and waning with the light of the central condensation, but still one. To study, to differentiate, to classify, opens a field of great interest and importance.

In closing we may be permitted to say, that however probable our result may be, we know that we have, strictly, proved nothing. The data at hand do not yield an accurate proof. On the one hand we need fuller special knowledge of the changes taking place in the hydrogen-spectrum; on the other we need from the telescope more accurate and more connected data. The investigation on the first head is, through the courtesy of the authorities presiding over Johns Hopkins University, going forward in Rowland's laboratory. The evidence is here presented, in its incomplete form, in the hope that some of those having the disposal of telescopes properly situated may be induced to devote them to this object.

Copeland, *Monthly Notices*, 1886.
Konkoly, *Astron. Nachr.*, No. 2712.
Von Gothard, *Astron. Nachr.*, No. 2719.
D'Arrest, *Undersogelser over de nebulose stjerner.* Copenhagen, 1872.
Bredichin, *Annales de Moscou*, Series 2, Vol. 2 and Vol. 3.
**This Journal, Vol. VII., No. 4.
†*American Journal of Science*, Feb. 1887.
*Vogel, *Bothkamper Beobachtungen.* Heft 1, 1872.
For the spectra employed:—
Cornu, *Journal de Physique*, 1886.
Hasselberg, *Academia Petropolitana*, Vol. XXXI.
Piazzi Smyth, Micrometrical Measures of Gaseous Spectra.
H. W. Vogel, *Beiblätter*, Bd. 4, 1880.
Schuster, *Philosophical Transactions*, 1880.
Angstrom and Thalén, *Nova Acta. Upsala*, [3] IX.

ELEMENTS AND EPHEMERIS OF COMET 1887 *c* (*BARNARD*.)

By H. V. EGBERT.

The very cloudy weather has interfered with the observation of this comet, and I have delayed the computation of new elements and ephemeris, hoping for data extending over a longer interval. But, that our observers may not be without means of easily finding the comet, I inclose the following, which are derived from the positions given below.

The middle place is from a filar-micrometer observation by Prof. Boss; while the first and third are from ring-micrometer comparisons, for which $\Delta\alpha$ and $\Delta\delta$ were kindly furnished by Mr. Barnard, and the star-places are Leiden determinations. The observation of January 30 is the latest at hand, and was but recently received.

1887	Greenw. M.T.	App. α	App. δ
Jan. 23	23ʰ 23ᵐ 55ˢ	19ʰ 7ᵐ 42ˢ.64	+25° 22′ 2″.7
26	23 2 12	19 15 45 .14	27 12 13 .1
30	23 35 37	19 26 56 .00	29 41 55 .9

Dudley Observatory, Albany, 1887 *February* 15.

ELEMENTS.

$$T = 1886 \text{ Nov. } 28.2171 \text{ Greenwich M.T.}$$

$$\left.\begin{array}{l}\omega = 31°\ 45'.7 \\ \Omega = 258\ \ 13\ .0 \\ i = 85\ \ 35\ .0\end{array}\right\}\text{M. Eq. } 1887.0$$

$$\log q = 0.17007$$

$$\text{C—O:}\quad \begin{array}{l}\Delta\lambda\cos\beta = +5'' \\ \Delta\beta = -6''\end{array}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1887	α (h m)	δ (° ′)	log Δ	Light
Feb. 26	20 51.8	+45 48	0.3500	0.70
Mar. 2	21 6.5	48 0	0.3556	0.65
6	21 21.8	50 6	0.3618	0.62
10	21 37.6	52 6	0.3687	0.58
14	21 54.0	53 58	0.3761	0.54
18	22 11.0	55 42	0.3840	0.50
22	22 28.5	57 17	0.3922	0.47
26	22 46.4	58 44	0.4008	0.44
30	23 4.8	60 3	0.4097	0.40

Light at discovery is taken as unity.

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COMET 1887 *d*.

Another very faint and rapidly moving comet was detected by Mr. E. E. BARNARD, at Nashville, on the night of February 16. The following early observations have been received from various sources:

1887	M.T. of place		α	δ	Observer
	h m s		h m s	° ′ ″	
Feb. 16	12 23 14	Nashville	8 2 41.8	—15 58 38	Barnard
17	8 50 12	Cambridge	7 42 27.1	—12 14 6	Sawyer
17	9 8 52	Cambridge	7 42 5.5	—12 10 18	Wendell
18	8 33 12	Nashville	7 17 19.5	— 7 17 38	Barnard
19	9 20 11	Albany	6 54 18.1	— 2 34 56	Boss
19	9 23 18	Cambridge	6 54 26.5	— 2 36 7	Wendell
22	9 20 19	Albany	5 55 23.6	+ 9 38 50	Boss

ELEMENTS AND EPHEMERIS OF COMET 1887 *d* (BARNARD).

BY LEWIS BOSS.

A letter, which I received yesterday from Mr. BARNARD, shows that the epoch of his observation of February 18 was wrongly transmitted to me in the telegram, and erroneously given in the *Science Observer* circular, where it was used by me as the middle observation in computing an orbit of Comet *d*. The error amounts to an hour, and the true epoch is earlier than that printed in the *Science Observer*. This unfortunate circumstance has so destroyed the efficieney of the ephemeris based on that computation, that I hasten to furnish another, based on BARNARD's discovery-observation February 16, and others by myself on February 19 and 22. The observations were corrected for parallax, aberration, etc., by means of approximate values of Δ which do not seriously differ from those resulting from the new elements, which are as follows:

$$T = 1887 \text{ March } 28.4727 \text{ Greenw. M.T.}$$
$$\left.\begin{aligned} \omega &= 36^\circ\ 36'.8 \\ \Omega &= 135\ \ 27.9 \\ i &= 139\ \ 45.4 \end{aligned}\right\} 1887.0$$
$$\log q = 0.00258$$

Dudley Observatory, 1887 *February* 23.

Comparison with the observation of February 19, gives (C—O):

$$\Delta\lambda \cos\beta = +0'.6\,; \quad \Delta\beta = +0'.1$$

A like comparison with the mean of the determinations by SAWYER and WENDELL on February 17 gives:

$$\Delta\lambda \cos\beta = +0'.3\,; \quad \Delta\beta = +0'.1.$$

The adopted value of the ratio of geocentric distances used in the computation was very near the truth; and these residuals must be ascribed to the influence of errors of observation. The comet was nearest the earth, February 17, and its brightness is rapidly decreasing, so that it is doubtful if it can be observed beyond February.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1887	α	δ	log Δ	Light
	h m s	° ′		
Feb. 25	5 13 16	+17 43.9	9.5896	0.6
27	4 51 25	21 32.7	9.6464	0.5
Mar. 1	4 33 51	24 22.7	9.7000	0.4
3	4 19 36	26 31.5	9.7496	0.3
7	3 58 10	29 30.4	9.8370	0.2
11	3 42 56	31 27.2	9.9105	0.15

CORRIGENDA.

No. 148, p. 30. In Mr. SAWYER's article upon the New Variable in *Sagittarius*, the computed times of maxima and minima were inadvertently transcribed instead of the observed ones. By adding the quantities O—C to the times as given, the true observed moments will be obtained.

No. 151, p. 49. In col. 2, last line, *for* DM. 67°,645, *read* DM. 67°,945.

p. 50. In col. 1, line 3, *for* DM. 69°,942, *read* DM. 67°,942.

p. 50. In col. 2, line 19, *for* < DM. 19°,3097 *read* > DM. 19°,3097.

p. 56. In first line of Corrigenda, *for* number, *read* member.

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THE

ASTRONOMICAL JOURNAL.

No. 154.

VOL. VII. BOSTON, 1887 MARCH 15. NO. 10.

RELATIVE POSITIONS OF 63 SMALL STARS IN THE *PLEIADES*.

By Prof. A. HALL, U.S N.

(Communicated by Captain R. L. Phythian, U.S.N., Superintendent of the Naval Observatory, Washington.)

In the autumn of 1885, Prof. H. A. Newton suggested that I should make some micrometrical measurements of a number of the small stars in the *Pleiades*, for the purpose of connecting these stars with the brighter ones of this group, whose relative positions had been measured by Bessel and Schlüter, 1829–1841, and which were being reobserved by Dr. Elkin with the heliometer of the Yale College Observatory.

It seems probable that the stars of such a group will have a common proper-motion; and to me it seems probable also that the small stars will be found to be connected physically with the larger ones. But in any case it will be interesting in the future to have means of testing the question of the proper-motion of the bright stars with respect to the smaller ones. Again, the great number of small stars that are visible in the nebulas of *Orion* and *Andromeda*, and in other nebulas, seem to indicate a physical connection of clusters of stars and nebulas; and it is possible that the thin nebula which is spread over a large portion of the *Pleiades* may once have had a more intimate connection with the stars of this group. Although changes in such distant systems can be determined only after long intervals of time, the preceding considerations led me to undertake the observations suggested by Prof. Newton.

Recently, however, the photographic art has made great progress, and probably astronomical work of this kind may be done more easily by its aid. The *Pleiades* come into position for observation during the winter season, when the weather is generally very unfavorable, and we have here a case where photography may be applied with the greatest advantage. It seems best, therefore, to stop such measurements for the present, and wait for what the photographic method will furnish.

The following table contains the results of my observations. The first column gives the date of the observation, in years and decimals of a year. The second column gives the sidereal time to the nearest tenth of an hour, which has been used to compute the differential refraction. Then follows the name of the star of reference taken from Bessel's Catalogue in the *Astronomische Untersuchungen*, Band I., pp. 237–238. The next column gives the number of the small star in this list. The observed angle of position and distance, with the corrections for differential refraction, $\Delta\rho$, follow in the next columns. Each of the observed angles depends on four settings of the position-circle. In order to avoid so much turning of the micrometer-screw for the large distances, a few of the earlier observations were made with the movable wire on one side of the fixed wire, the coincidence being noted, and four bisections of the stars were made for each observation. On the next night the movable wire was placed on the other side of the fixed one, and the same distance was measured. But this method was soon given up, as it seemed liable to constant errors, and most of the distances were measured by reversing the wires on each night. In this case two double distances were measured. The magnitudes of these small stars were estimated by assuming that the limit of visibility in the 26-inch objective is a magnitude of 16.3. The estimates of magnitudes will be subject to some uncertainty, as my scale is not well fixed; and moreover the condition of the sky, which was generally below the average, would have much influence with such faint objects. The observations were all made with a magnifying power of 383, and with bright wires in a dark field. In order to avoid misunderstanding, it should be stated that I have not endeavored to observe all the small stars near the star of reference.

The average magnitude of these small stars is 12.4. The average of the observed distances is 115″.0, and the probable errors of a single observation are as follows:

in angle, $\pm 0''.421$; in distance, $\pm 0''.187$, from 142 observations.

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Date	Sid. Time	Star	No.	p	Δp	s.	Δρ	Mag.	Notes
	h			°	°	″	″		
1886.131	4.6	*Celaeno*		259.48	0.00	86.93	+0.02		
1886.134	4.4	"		259.60	0.00	86.68	0.02		
1887.084	3.1	"		259.65	0.00	86.40	0.02		
1886.450		Mean	1	259.58		86.69		11	
1886.134	4.7	*Celaeno*		194.86	0.00	218.09	0.07		
1886.147	4.7	"		194 85	0.00	217.91	0.07		
1887.084	2.9	"		194.85	0.00	217.61	0.06		
1886.455		Mean	2	194.85		217.94		10	windy
1886.109	4.0	*Electra*		143.70	0.00	105.87	0.03		
1886.112	3.7	"		144.22	0.00	105.76	0.03		
1886.110		Mean	3	143.96		105.85		13	
1886.109	4.2	*Electra*		122.05	0.00	150.28	0.04		
1886.112	4.0	"		122.15	0.00	150.40	0.04		
1886.110		Mean	4	122.10		150.38		13	
1886.109	4.4	*Electra*		191.50	0.00	221.10	0.07		
1886.112	3.6	"		191.42	0.00	221.24	0.07		
1886.110		Mean	5	191.46		221.24		11	
1886.131	4.4	*Electra*		345.05	0.00	181.05	0.05		
1886.134	4.2	"		345.04	0.00	181.15	0.05		
1887.084	3.3	"		344.92	0.00	181.12	0.05		
1886.450		Mean	6	345.00		181.16		10	
1887.084	3.5	18 *m*		130.40	0.00	79.18	0.02		
1887.120	4.3	"		130.00	0.00	78.05	0.02		
1887.102		Mean	7	130.20		78.63		14	
1887.084	3.7	18 *m*		174.30	0.00	158.75	0.06		
1887.120	4.1	"		173.72	0.00	157.69	0.05		
1887.102		Mean	8	174.01		158.28		13	
1886.147	4.9	*Taygeta*		329.62	0.00	67.17	0.02		
1886.150	4.9	"		329.38	0.00	67.31	0.02		
1886.148		Mean	9	329.50		67.26		10	
1886.147	5.2	*Taygeta*		59.05	0.00	50.96	0.02		
1886.150	5.2	"		59.22	0.00	50.97	0.02		
1886.148		Mean	10	59.13		50.98		14	
1887.084	4.1	Anonyma 1		357.82	0.00	120.30	0.04		
1887.120	4.5	"		357.58	0.00	120.88	0.04		
1887.131	4.4	"		357.88	0.00	120.76	0.04		
1887.112		Mean	11	357.76		120.69		12	
1887.084	4.3	Anonyma 1		137.75	0.00	145.27	0.04		
1887.120	4.7	"		137.78	0.00	145.17	0.04		
1887.102		Mean	12	137.76		145.26		14	
1886.153	5.3	*Maja*		75.60	0.00	113.62	0.04		
1886.164	5.3	"		75.58	0.00	113.85	0.04		
1886.158		Mean	13	75.59		113.77		13	
1887.123	4.2	Anonyma 7		320.08	0.00	163.72	0.05		
1887.131	4.7	"		319.92	0.00	164.06	0.05		
1887.127		Mean	14	320.00		163.94		14	
1886.164	5.6	*Asterope*		73.40	0.00	170.94	0.06		
1886.166	5.6	"		73.55	0.00	171.09	+0.06		windy
1886.165		Mean	15	73.47		171.07		12	

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Date	Sid. Time	Star	No.	p	Δp	s.	Δρ	Mag.	Notes
	h			°	°	"	"		
1887.073	3.8	22 *l*		257.18	0.00	49.63	+0.01		
1887.076	3.8	"		256.50	0.00	49.94	0.01		
1887.074		Mean	16	256.84		49.79		14	
1887.139	5.3	Anonyma 8		8.85	0.00	18.55	0.01		fog
1887.147	4.9	"		9.20	0.00	18.31	0.01		
1887.143		Mean	17	9.02		18.44		13.5	
1887.123	4.5	*Merope*		178.50	0.00	114.89	0.03		
1887.131	5.2	"		178.45	0.00	114.61	0.03		
1887.127		Mean	18	178.47		114.78		14	
1887.123	4.7	*Merope*		335.90	0.00	141.84	0.04		
1887.131	4.9	"		335.95	0.00	141.27	0.04		
1887.127		Mean	19	335.92		141.59		12	
1887.139	5.7	Anonyma 10		37.28	0.00	115.11	0.04		haze
1887.147	5.1	"		37.50	0.00	115.60	0.04		
1887.143		Mean	20	37.39		115.39		14	
1887.073	4.1	Anonyma 12		295.62	0.00	100.14	0.03		
1887.076	3.4	"		295.48	0.00	100.27	0.03		
1887.074		Mean	21	295.55		100.23		13	
1887.073	4.3	Anonyma 12		189.50	0.00	128.24	0.04		
1887.076	3.6	"		189.25	0.00	128.61	0.04		
1887.074		Mean	22	189.37		128.46		13	
1887.062	2.9	Anonyma 14		231.70	0.00	69.89	0.02		
1887.065	2.9	"		231.70	0.00	70.24	0.02		
1887.064		Mean	23	231.70		70.08		11	
1887.062	3.2	Anonyma 14		254.15	0.00	154.01	0.04		
1887.065	3.2	"		254.38	0.00	154.07	0.04		
1887.064		Mean	24	254.26		154.08		11	
1887.062	3.4	Anonyma 14		245.28	0.00	136.19	0.04		
1887.065	3.4	"		245.12	0.00	136.55	0.04		
1887.064		Mean	25	245.20		136.41		12	
1887.068	3.7	Anonyma 19		278.25	0.00	25.79	0.01		
1887.071	2.8	"		278.72	0.00	26.01	0.01		
1887.153	5.9	"		279.75	0.00	26.00	0.01		
1887.097		Mean	26	278.91		25.94		14	
1887.071	3.6	Anonyma 20		102.90	0.00	36.45	0.01		
1887.073	3.3	"		102.45	0.00	36.33	0.01		
1887.072		Mean	27	102.67		36.40		15.5	
1887.071	3.8	Anonyma 20		64.95	0.00	129.78	0.04		
1887.073	3.1	"		64.88	0.00	130.20	0.04		
1887.072		Mean	28	64.91		130.03		12	
1887.071	4.0	Anonyma 21		326.28	0.00	7.01	0.00		
1887.073	3.5	"		329.18	0.00	6.94	0.00		
1887.076	3.2	"		329.95	0.00	6.90	0.00		
1887.073		Mean	29	328.47		6.95		11	
1887.139	6.0	Anonyma 22		263.22	0.00	5.78	0.00		haze
1887.147	5.3	"		261.22	0.00	5.67	0.00		
1887.153	5.1	"		262.70	0.00	6.27	+0.00		windy
1887.146		Mean	30	262.38		5.91		12	

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Date	Sid. Time	Star	No.	p	Δρ	s.	Δρ	Mag.	Notes
	h			°	°	"	"		
1887.147	5.4	Anonyma 22		174.90	0.00	59.26	+0.02		
1887.153	5.3	“		174.75	0.00	59.01	0.02		
1887.150		Mean	31	174.82		59.15		14	
1887.071	3.3	Anonyma 24		19.42	0.00	88.15	0.03		
1887.073	2.8	“		20.08	0.00	89.17	0.03		
1887.076	3.0	“		19.45	0.00	87.78	0.03		
1887.073		Mean	32	19.65		88.40		15.5	
1885.947	0.2	*Alcyone*		226.30	—0.01	78.82	0.02		blazing images
1885.950	0.8	“		226.20	—0.01	79.36	0.02		
1885.948		Mean	33	226.24		79.11		15	
1885.947	0.5	*Alcyone*		229.08	—0.01	144.30	0.04		blazing images
1885.950	1.0	“		229.10	—0.01	144.85	0.04		
1885.948		Mean	34	229.08		144.61		13	
1885.961	1.4	*Alcyone*		54.05	—0.01	199.03	0.06		
1885.967	1.2	“		53.98	—0.01	199.56	0.06		
1885.983	0.6	“		54.00	—0.01	199.72	0.06		faint, misty
1885.986	0.8	“		54.00	—0.01	199.71	0.06		
1885.974		Mean	35	54.00		199.56		11	
1885.961	1.6	*Alcyone*		44.78	—0.01	219.21	0.06		
1885.967	1.0	“		44.85	—0.01	220.10	0.06		
1885.983	0.4	“		44.78	—0.01	219.58	0.06		misty
1885.986	0.6	“		44.72	—0.01	220.15	0.06		
1885.974		Mean	36	44.77		219.82		11	
1885.950	1.4	Anonyma 25		209.58	0.00	48.52	0.01		
1885.961	1.0	“		209.80	0.00	48.40	0.01		
1885.956		Mean	37	209.69		48.47		13	
1887.062	3.8	Anonyma 28		295.40	0.00	173.36	0.05		
1887.068	2.7	“		295.35	0.00	173.02	0.05		
1887.065		Mean	38	295.37		173.24		12	
1885.950	1.3	Anonyma 29		216.28	0.00	71.63	0.02		
1885.961	0.8	“		216.95	0.00	71.61	0.02		
1885.956		Mean	39	216.61		71.64		15	
1887.147	5.7	26 *s*		234.78	0.00	77.36	0.02		windy
1887.153	5.5	“		235.10	0.00	77.58	0.02		
1887.150		Mean	40	234.94		77.49		14	
1887.147	5.8	26 *s*		332.68	0.00	78.30	0.02		
1887.153	5.7	“		332.88	0.00	79.15	0.02		
1887.150		Mean	41	332.78		78.74		15	
1885.986	1.3	*Atlas*		282.45	—0.01	92.69	0.03		
1885.991	0.8	“		282.78	—0.01	93.04	0.03		
1885.988		Mean	42	282.60		92.89		13	
1885.986	1.5	*Atlas*		42.48	0.00	46.87	0.01		
1885.991	1.0	“		42.22	0.00	46.81	0.01		
1885.988		Mean	43	42.35		46.85		15	
1885.986	1.7	*Atlas*		63.38	0.00	112.04	0.03		a triple star
1885.991	1.3	“		63.92	—0.01	112.38	0.03		
1885.988		Mean	44	63.65		112.24		14	
1885.997	1.0	*Atlas*		238.45	—0.01	216.39	0.06		
1886.005	2.0	“		238.52	0.00	216.41	+0.06		
1886.001		Mean	45	238.48		216.46		10	

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ASTRONOMICAL JOURNAL, NO. 154.—SUPPLEMENT.

RING-MICROMETER OBSERVATIONS OF COMET 1887 *d* (*Barnard, Feb. 16*)

MADE AT THE DUDLEY OBSERVATORY

BY LEWIS BOSS.

1887	Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Feb. 19	9 20 11	1	3	+4 58.6	+5 1	6 54 18.1	− 2 34 56	8.669	0.796
22	8 34 57	2	3	−2 47.4	−3 37	5 55 56.3	+ 9 31 39	8.975	0.690
22	9 20 19	3	5	−0 46.9	+0 14	5 55 23.7	+ 9 38 49	9.251	0.689
25	11 35 34	4	7	−2 18.1	+2 11	5 11 4.6	+18 7 14	9.636	0.702
25	11 50 5	5	5	+1 52.8	+5 21	5 10 55.9	+18 8 49	9.645	0.711

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	6 49 18.73	+0.82	− 2 39 42.1	−15.1	Cordoba and Karlsruhe
2	5 58 43.19	+0.55	+ 9 35 27.7	−11.8	Albany Transit-Circle
3	5 56 10.04	+0.54	+ 9 38 46.5	−11.8	μ *Orionis*
4	5 13 22.44	+0.28	+18 5 11.7	− 8.7	Weisse's Bessel, 319
5	5 9 2.82	+0.25	+18 3 37.0	− 8.6	Weisse's Bessel, 185

NOTES.

The observations of February 19 and February 22, were made in great haste, as opportunity offered through breaks in the clouds. The placing of the objects in the ring was not always the most favorable for accurate differences of declination. At the observation of February 25, this comet appeared to me to be at least three times as bright as the Finlay comet, which I had observed on the same evening. A part of the comparisons in the first set of Feb. 25 was made after those of the second set. The computed values of log $p\Delta$ in this case correspond to the mean values of that quantity, rather than to the mean of the times.

NOTE ON COMET 1886*e* (*FINLAY.*)

From a letter of Prof. Lewis Boss to the Editor.

My last observation of the Finlay Comet was made on the evening of Feb. 25, when I compared it with Weisse III. 655, with this resulting comet-position:

	Albany M.T.	App. α	App. δ
1887 Feb. 25	9ʰ 34ᵐ 28ˢ	3ʰ 34ᵐ 31ˢ.4	+21° 28′ 47″

This is the mean of eight ring-micrometer determinations (13-inch equatorial), and gives as corrections to the ephemeris published in No. 150 of the *Astr. Journal:* $\Delta\alpha = +7^s.0$, $\Delta\delta = +19''$. On the occasion of this observation the atmosphere appeared to me to be remarkably pure and quiet, yet the comet was so faint that I was not always able to see it continuously across the field of view. As the comet on March 11 is less than two-thirds its brightness on Feb. 25, it does not appear to me worth while to extend the ephemeris. Should others desire to do so they are cautioned to omit the negative sign in connection with the logarithms contained in the equations of heliocentric coordinates, p. 43, No. 150 *Astr. Journal.*

CORRIGENDA.

No. 150. p. 43. Omit the *n*s prefixed to the logarithms in the equations of the coordinates for 1886.0 and 1887.0.

p. 47. Ephemeris of Comet of Finlay: Transfer the value of the "App. α" opposite Feb. 25 to March 3, and raise all other values one line; over the figures in the column "Hourly Motion," for ′ read ″; in column "log Δ," opposite March 3, for 0.900574, read 0.200574.

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Date	Sid. Time	Star	No.	p	Δρ	s.	Δρ	Mag.	Notes
	h			°	°	″	″		
1885.997	1.2	*Atlas*		189.85	0.00	160.66	+0.04		
1886.005	2.2	"		189.55	0.00	160.80	0.05		
1886.001		Mean	46	189.70		160.78		11	
1885.997	1.4	*Atlas*		125.40	0.00	176.87	0.07		
1886.005	2.5	"		125.52	0.00	177.75	0.06		
1886.001		Mean	47	125.46		177.37		11	
1885.997	1.7	*Atlas*		215.85	0.00	73.24	0.02		
1887.123	5.0	"		215.00	0.00	73.71	0.02		
1886.560		Mean	48	215.42		73.49		16	
1886.008	1.7	*Plejone*		223.42	0.00	170.54	0.05		
1886.084	3.8	"		223.42	0.00	172.47	0.05		
1886.106	4.2	"		223.40	0.00	171.82	0.05		
1886.066		Mean	49	223.41		171.66		12	
1886.008	1.9	*Plejone*		273.20	0.00	219.38	0.07		
1886.019	1.5	"		273.12	—0.01	219.94	0.08		clouds
1886.013		Mean	50	273.16		219.73		10	
1886.084	4.0	*Plejone*		79.62	0.00	96.75	0.03		
1886.106	4.4	"		79.22	0.00	96.95	0.03		
1886.095		Mean	51	79.42		96.88		15	
1886.008	2.2	*Plejone*		67.45	0.00	143.56	0.04		hazy
1886.084	3.6	"		67.32	0.00	141.60	0.04		
1886.106	4.0	"		67.28	0.00	143.00	0.04		
1886.066		Mean	52	67.35		142.76		14	
1886.985	2.1	Anonyma 31		15.62	0.00	66.26	0.02		
1887.010	1.6	"		15.72	0.00	66.04	0.02		
1886.997		Mean	53	15.67		66.17		10	
1886.985	2.4	Anonyma 31		239.88	0.00	83.51	0.02		
1887.010	1.8	"		239.58	0.00	83.30	0.02		
1886.997		Mean	54	239.73		83.42		10	
1886.985	2.6	Anonyma 31		270.48	0.00	145.34	0.04		
1887.010	2.0	"		270.58	0.00	145.17	0.04		
1886.997		Mean	55	270.53		145.29		12	
1886.985	2.8	Anonyma 31		225.95	0.00	149.26	0.04		
1887.010	2.2	"		226.25	0.00	149.00	0.04		
1886.997		Mean	56	226.10		149.17		14	
1886.971	2.4	Anonyma 32		85.28	0.00	117.69	0.03		
1886.974	1.2	"		85.28	—0.01	117.37	0.04		
1886.985	1.5	"		85.45	—0.01	117.56	0.04		
1887.131	5.4	"		85.75	0.00	117.49	0.04		
1887.015		Mean	57	85.44		117.56		12	
1886.971	2.6	Anonyma 32		107.32	—0.01	184.93	0.06		
1886.974	1.4	"		107.38	—0.01	184.46	0.07		
1886.985	1.8	"		107.38	—0.01	184.98	0.06		
1886.977		Mean	58	107.35		184.85		12	
1887.131	5.7	Anonyma 32		209.62	0.00	163.60	0.05		
1887.139	5.0	"		209.65	0.00	163.34	0.05		
1887.135		Mean	59	209.63		163.52		14	
1887.013	1.5	Anonyma 34		103.02	—0.01	96.50	0.04		
1887.068	3.1	"		103.22	0.00	96.13	+0.04		
1887.040		Mean	60	103.12		96.35		10	

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Date	Sid. Time	Star	No.	p	Δρ	s.	Δρ	Mag.	Notes
	h			°	°	"	"		
1887.013	2.2	Anonyma 34		198.15	0.00	118.84	+0.03		
1887.068	3.3	"		197.92	0.00	118.85	0.03		
1887.040		Mean	61	198.03		118.87		12	
1887.134	4.4	Anonyma 37		55.42	0.00	62.92	0.02		
1887.139	4.5	"		55.80	0.00	62.81	0.02		
1887.136		Mean	62	55.61		62.88		11.5	
1887.134	4.6	Anonyma 37		218.40	0.00	41.42	0.01		foggy
1837.139	4.7	"		218.75	0.00	40.85	+0.01		
1887.136		Mean	63	218.57		41.14		11.5	

Naval Observatory, 1887 *March* 1.

OBSERVATIONS OF COMETS

MADE WITH THE 9.6 INCH EQUATORIAL AT THE U.S. NAVAL OBSERVATORY

BY PROF. E. FRISBY.

(Communicated by the Superintendent.)

Washington M.T. 1887.0	*	No. Comp.	☄ — * Δα	Δδ	☄'s apparent α	δ	log pΔ for α	for δ
			COMET 1887 *b* (*Brooks.*)					
Feb. 12 9h 14m 13s.4	1	20 , 4	−3m 12s.91	+ 1′ 24″.5	1h 27m 25s.97	+75° 0′ 27″.0	0.242	9.335
16 8 34 7.8	2	20 , 4	+1 30.76	+ 2 30.8	2 14 20.25	+70 42 37.1	0.088	*n*0.101
18 15 30 7.2	3	10 , 2	−1 8.89	− 5 49.8	2 33 26.84	+68 4 10.9	9.571	0.912
			COMET 1886 *e* (*Finlay.*)					
Feb. 16 10 9 52.8	4	20 , 2	−0 3.53	+14 54.9	3 5 6.32	+19 32 43.8	9.669	0.656
			COMET 1887 *c* (*Barnard.*)					
Feb. 18 17 12 27.1	5	10 , 2	−3 26.68	− 5 28.3	20 25 24.78	+41 24 5.8	9.606	9.865
			COMET 1887 *d* (*Barnard.*)					
Feb. 24 8 47 19.1	6	15 , 3	−2 17.37	+ 1 6.9	5 25 14.51	+15 31 20.0	9.439	0.582

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 30 39.10	−0.22	+74 58 51.6	+10.9	Oe. Arg. N. 1720
2	2 12 49.66	−0.17	+70 39 56.6	+ 9.7	Oe. Arg. N. 2618
3	2 34 36.02	−0.29	+68 9 51.7	+ 9.0	Radcliffe 762
4	3 5 10.05	−0.20	+19 17 55.0	− 6.1	Berliner Jahrbuch
5	20 28 52.83	−1.37	+41 29 39.2	− 5.1	Radcliffe 4849
6	5 27 31.65	+0.23	+15 30 22.8	− 9.7	Weisse's Bessel, V. 750

The apparent place of * 4 was taken immediately from the *Berliner Jahrbuch*.

The star, Radcliffe 4849, which is Lal. 39704,5 = Groombr. 3215 = Weisse's Bessel XX. 960.1, seems to have a considerable proper-motion, amounting apparently to about −0s.014 and +0″.53 annually.

1887 *February* 25.

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OBSERVATIONS OF COMET 1887 *d* (*Barnard, Feb. 16*)

MADE AT THE HARVARD COLLEGE OBSERVATORY

BY O. C. WENDELL, ASSISTANT.

(Communicated by Prof. E. C. PICKERING, Director.)

Greenwich M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
Feb. 17 12ʰ 56ᵐ 28ˢ	1	5	+1ᵐ 36.86ˢ	+ 2′ 22.5″	7ʰ 43ᵐ 5.80ˢ	−12° 21′ 48.2″	n9.278	0.849
17 13 53 23	2	5	+1 4.58	− 1 45.9	7 42 5.51	−12 10 18.1	n8.914	0.855
19 14 7 49	3	5	+0 31.94	−11 52.5	6 54 26.47	− 2 36 6.6	n8.722	0.794
25 13 48 21	4	5	−1 18.40	+ 0 10.0	5 12 26.59	+17 52 35.7	9.399	0.598
28 14 3 6	5	5	−1 31.42	− 2 1.5	4 41 27.30	+23 9 45.2	9.544	0.490

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	7ʰ 41ᵐ 27.85ˢ	+1.09ˢ	−12° 23′ 55.0″	−15.7″	Lal. 15175
2	7 40 59.84	+1.09	−12 8 16.5	−15.7	Weisse's Bessel, VII. 1204
3	6 53 53.69	+0.84	− 2 23 59.1	−15.0	Lamont, V. 1161
4	5 13 44.71	+0.28	+17 52 34.4	− 8.7	Lal. 9952
5	4 42 58.64	+0.08	+23 11 53.3	− 6.6	Weisse's Bessel, IV. 918

RING-MICROMETER OBSERVATIONS OF COMETS

MADE AT THE VANDERBILT UNIVERSITY OBSERVATORY

BY E. E. BARNARD.

1887 Nashville M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ
COMET 1887 *c* (*Barnard, Jan. 23.*)						
Jan. 30 17ʰ 48ᵐ 29ˢ	1	7	−0ᵐ 32.07ˢ	−14′ 54.9″	19ʰ 26ᵐ 56.00ˢ	+29° 41′ 55.9″
COMET 1887 *d* (*Barnard, Feb. 16.*)						
Feb. 16 12 23 23	2	4	−1 37.79	−3 22.8	8 2 41.83	−15 58 37.8
18 8 6 30	3	7	−1 42.38	−0 9.2	7 17 46.34	− 7 22 31.5
22 7 56 51	4	7	−0 23.33	−4 13.8	5 55 47.12	+ 9 34 21.9

Comet *d* very faint, round, average size.

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	19ʰ 27ᵐ 29.58ˢ	−1.51ˢ	+29° 56′ 51.5″	− 0.7″	Leiden A.G. Zones
2	8 4 18.42	+1.20	−15 55 4.3	−10.7	½ (Cape 4143 + Arg. Gen. Cat. 10804)
3	7 19 27.74	+0.98	− 7 22 9.8	−12.5	Compar. with Arg. Gen. Cat. 9600
4	5 56 9.92	+0.53	+ 9 38 47.5	−11.8	Yarnall 2490

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RING-MICROMETER OBSERVATIONS OF COMET 1887 *b* (*BROOKS*)

MADE AT THE LEHIGH UNIVERSITY OBSERVATORY

By C. L. DOOLITTLE.

1887 Greenwich M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
Feb. 9 12ʰ 9ᵐ 18ˢ	*a*	3	—9ᵐ 15.73ˢ	— 3′ 17.4″	0ʰ 31ᵐ 21.59ˢ	77° 48′ 0.8″	0.190	*n*0.340
13 14 30 33	*b*	6	—1 0.73	—17 17.7	1 41 30.64	73 58 14.5	0.135	9.728
19 13 39 12	*c*	3	+3 28.11	— 5 46.3	2 38 33.97	67 14 57.8	9.930	*n*9.972
19 14 15 6	*c*	3	+3 37.89	— 7 23.3	2 38 43.75	67 13 20.8	9.963	*n*8.806

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
a	0ʰ 40ᵐ 38.98ˢ	—1.66ˢ	77° 51′ 6.9″	+11.3″	Argelander, Z.148, no. 139
b	1 42 32.10	— .73	74 15 21.6	+10.6	Argelander, Z.168, no. 48
c	2 35 6.21	— .35	67 20 35.4	+ 8.7	Yarnall, 1173

COMETS OF THE YEAR 1886.

The dates are in Greenwich M.T., and the elements only approximate.

Designation	Discoverer	Perihelion 1886	☊	ω	i	q	Discovery	Synonym	
I	Fabry	April 5.96	36° 23′	126° 36′	82° 37′	0.642	1885 Dec. 1	1885 *d*	
II	Barnard	May 3.28	68 19	119 36	84 25	0.479	Dec. 3	1885 *e*	
III	Brooks	May 4.67	288 6	39 1	100 33	0.842	1886 April 30	1886 *b*	
IV	"	June 6.78	52 6	176 50	13 24	1.360	May 22	1886 *c*	periodic
V	"	June 7.40	192 42	201 13	87 44	0.270	April 27	1886 *a*	
VI	Finlay	Aug. 19.	101 56	174 8	14 27	0.883	Aug. 19	1886 *d*	Winnecke
VII	"	Nov. 22.39	52 26	315 7	3 2	0.998	Sept. 26	1886 *e*	periodic
VIII	Barnard	Nov. 28.22	258 13	31 46	85 35	1.479	1887 Jan. 23	1887 *c*	
IX	"	Dec. 16.54	137 23	86 22	101 37	0.663	1886 Oct. 4	1886 *f*	

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THE

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NOTES ON SOME PLACES OF AUWERS'S FUNDAMENTAL CATALOGUE.

By S. C. CHANDLER, Jr.

In A.N. 2713 Dr. Auwers has shown that the discrepancy in the present place of *ν Ursae Majoris*, which I had pointed out in A.N. 2687, reveals a source of weakness in the proper-motions of some other stars of his catalogue; namely, in all those cases where the adopted place shows a large correction for the position "Greenwich 1861." In consequence he is of the opinion that a closer approach to the true places of this class would in all probability be attained by adding to the position deduced from the catalogue a correction to the proper-motion, corresponding to the assumption that Greenwich 1861 is in error. He gives a list of objects which from this circumstance may be regarded as especially weak. It is of interest, of course, to obtain further evidence with regard to these suspected proper-motions. Having, therefore, a few observations of about half of these stars, I have thought it worth while to make a comparison, and the result has been to confirm the probable existence of such a defect as the one in question in most of the cases examined.

Thus, in the column "Observed," is given the mean correction to the right-ascension of the Berlin *Jahrbuch*, deduced from such almucantar-observations as I happen to have; and, in the column "Computed," the corresponding correction due to the accumulated error in the proper-motion from the assigned cause.

		Obs.	Correction 1885 Observed	Correction 1885 Computed
81	*ε Aurigae*	5	—0.030	+0.026
139	h *Ursae Majoris*	7	+0.075	+0.045
150	9 H. *Draconis*	7	+0.190	+ ?
159	*ν Ursae Majoris*	13	—0.135	—0.049
[338]	Bradley 6	1	+0.197	+ ?
[343]	Bradley 82	1	+0.197	+ ?
369	Groombr. 848	11	—0.022	— ?
[381]	36 *Camelop.*	2	+0.045	+0.060
[393]	24 H *Camelop.*.	4	+0.019	+ ?
406	Bradley 1147	1	+0.027	+0.077
[413]	*ρ Ursae Majoris*	2	+0.016	+0.024
[464]	2 H. *Ursae Minoris*	4	—0.124	— ?
467	1 H. *Ursae Minoris*	8	+0.030	+ ?
[482]	f *Draconis*	6	+0.002	+0.044
[525]	31 *Cephei*	6	+0.006	—0.038
529	*π Cephei*	8	—0.058	—0.053

A query is placed against those stars which are not in Bradley, or in which Dr. Auwers gives no data from which the numerical amount of the error can be calculated. It will be seen, however, that in fourteen cases out of sixteen the observations give the same sign to the correction as results from the assumed error in the assigned proper-motion.

While it is certainly true, as Dr. Auwers has remarked, that it is not advisable to introduce, into the Berlin ephemerides, alterations of the places of particular stars—even where it is undoubted that such individual changes would be improvements—and that it is more conformable to retain the catalogue unaltered until such time as the whole can be presented in a revised form—it is nevertheless equally true that such places as are found, from time to time, to be weak, should have a mark of warning placed against them, in order that observers who use the list for clock and instrumental corrections may be able to discriminate. It is therefore doing a useful service to signalize such stars. That so few deviations of importance have thus far developed themselves in so large a list is indeed surprising. There could be no higher evidence of the admirable character of the catalogue, the epoch of whose right-ascensions now dates back a quarter of a century, and which it was not originally contemplated would be required to subserve the purpose of a general fundamental catalogue up to the present time.

In the course of my observations with the almucantar, in 1884 and 1885, a considerable number of apparently divergent cases were met with, some of which were communicated to the *Astronomische Nachrichten* (Nos. 2687 and 2691). A more complete list is contained in the following tabulation, where the result of a comparison with various other authorities is also incorporated. The list comprises twelve *Hauptsterne* and the same number of *Zusatzsterne*. Four of the former and two of the latter class (those whose numbers are marked * in the table) were included in the previous publication; the remainder are new. All but five are contained in the apparent-place ephemerides of the Berlin *Jahrbuch*; the five exceptions have their numbers in brackets. Numbers 137, 203, 224, 226, 338, 360, 464, 472 and 537 are not in Bradley, or he has no right-ascension for

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them, and he has only one observation of 171 and 447; and the proper-motions of the Fundamental Catalogue for these stars have therefore been noted as uncertain by AUWERS.

HAUPTSTERNE.

No. Fund. Cat. Name		137* 1 H. Draconis	139 *h* Urs. Maj.	159* *υ* Urs. Maj.	162 *λ* Draconis	171 *κ* Draconis	203* *γ* Urs. Min.
Pulkowa	1845	49 —0.120	48 +0.006	47 +0.020	57 +0.018	39 —0.021	48 +0.116
Greenwich	1861	6 +0.009	6 —0.198	5 +0.195	11 +0.026	20 —0.027	5 +0.102
Pulkowa	1865	+0.061	+0.051	—0.040	+0.042	+0.053	—0.030
Greenwich	1872	7 —0.135	9 +0.009	13 0.000	22 —0.089	30 —0.027	22 —0.134
Cambridge	1873	36 +0.156	2 +0.017	10 —0.059	58 —0.021	29 —0.001	28 —0.048
"	1877	22 +0.274	3 —0.018		26 —0.030	30 +0.064	40 —0.066
Greenwich	1878	1 +0.318		4 —0.128	7 —0.092	1 +0.033	11 —0.038
"	1882	3 —0.111	7 +0.069	3 —0.089	20 —0.042	8 +0.048	4 —0.149
Almucantar	1885	7 +0.243	7 +0.075	13 —0.135	8 —0.061	7 +0.098	12 —0.249

No. Fund. Cat. Name		224 *τ* Herculis	226* *η* Draconis	240 *β* Draconis	268 *γ* Lyræ	302 61 Cygni pr.	303 *ζ* Cygni
Pulkowa	1845	46 —0.031	48 +0.113	66 +0.005	22 —0.003	37 —0.081	28 +0.007
Greenwich	1861	35 —0.069	51 +0.058	57 +0.026	18 —0.010	70 —0.016	130 +0.007
Pulkowa	1865	+0.014	—0.049	—0.009	+0.006	+0.018	—0.008
Greenwich	1872	25 +0.060	20 —0.082	39 —0.012	6 +0.002	19 +0.053	93 —0.004
Cambridge	1873	8 +0.033	37 —0.135	39 —0.006	1 +0.012	31 +0.037	23 +0.017
"	1877	7 +0.030	29 —0.185	15 —0.026	12 +0.040	2 +0.072	29 +0.025
Greenwich	1878	1 +0.026	9 —0.175	4 —0.010	3 +0.045	2 +0.057	16 +0.051
"	1882	7 +0.116	14 —0.233	13 —0.032	4 +0.041	8 +0.093	30 +0.020
Almucantar	1885	3 +0.118	11 —0.177	2 —0.084	7 +0.057	2 +0.142	4 +0.062

ZUSATZSTERNE.

No. Fund. Cat. Name		[338] Bradley 6	360* 48 H. Cephei	383 22 H. Camel.	[429] 35 H. Urs. Maj.	436 Gr. 1771	439 3 Draconis
Pulkowa	1845			4 +0.052			
Greenwich	1861	5 —0.239	3 +0.127	3 —0.088		1 —0.044	4 +0.041
Pulkowa	1871	+0.090	+0.073	—0.011	+0.002	—0.011	+0.036
Greenwich	1872	12 +0.009	16 —0.143	5 +0.028	5 —0.004	7 +0.049	7 —0.112
Cambridge	1873	21 +0.107	25 +0.071	45 +0.031	7 —0.043	17 —0.012	8 +0.020
"	1877	14 +0.174	35 +0.033	25 +0.131	4 —0.033	2 —0.012	3 —0.097
Greenwich	1878		1 —0.010	2 —0.111	3 —0.233	3 +0.130	1 —0.205
"	1882	8 +0.462	5 +0.311	3 +0.066	4 —0.157	4 +0.196	7 —0.159
Almucantar	1885	1 +0.197	4 +0.224	5 +0.127	6 —0.099	4 +0.073	8 —0.128

No. Fund. Cat. Name		447 76 Urs. Maj.	[455] Gr. 2029	[464] 2 H. Urs. Min.	472* 19 Urs. Min.	[489] *φ* Draconis	537 41 H. Cephei
Pulkowa	1845						
Greenwich	1861	5 +0.001		4 +0.150	5 —0.080	9 +0.043	8 —0.006
Pulkowa	1871	—0.003	+0.005	—0.005	+0.090	—0.028	—0.020
Greenwich	1872	10 +0.006	3 —0.025	5 —0.063	13 —0.031	8 —0.001	9 +0.056
Cambridge	1873	3 —0.084	13 +0.051	19 —0.061	42 —0.001	22 —0.038	19 +0.054
"	1877		22 +0.002	6 —0.084	16 —0.015	3 —0.104	15 —0.004
Greenwich	1878	3 —0.003	1 +0.105		2 +0.172	2 —0.248	2 —0.016
"	1882	6 —0.089	10 +0.076	6 —0.104	3 +0.224	4 —0.147	8 +0.056
Almucantar	1885	5 —0.052	3 +0.180	4 —0.124	10 +0.312	3 —0.097	3 +0.073

As regards the comparison with the various authorities, the figures for Pulkowa 1845, 1865 and 1871, and Greenwich 1861 and 1872 are taken directly from the data supplied in Publication XIV., *Astr. Ges.*, in which were employed all the Greenwich observations up to 1876 and the Cambridge observations to 1872. For the last I have substituted the results of ROGERS's "Catalogue of 1213 Stars," divided into two groups, comprising observations before and after 1875.0, and have entered them as Cambridge 1873 and 1878, respectively, after applying the systematic corrections given in A.N. 2687. The means of the Greenwich observations from 1877 to 1879, and from 1880 to 1884, inclusive, are entered

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as Greenwich 1878 and 1882, respectively, applying AUWERS's systematic corrections for Greenwich 1872. The assumption that these would prevail for the later Greenwich observations was not made without examination. That would not have been entirely safe, for this reason, if for no other, that since 1876 different corrections to the Naut. Alm. places of the clock-stars have been in use at Greenwich; although, to be sure, these corrections were based on the Nine-Year Catalogue, 1868–1876, from which AUWERS's corrections were derived. A thorough investigation being out of the question, merely for the purpose of this discussion, about 60 stars were taken at random, and the mean of the Greenwich observations from 1880 to 1885 were compared with the Berlin *Jahrbuch*, in groups of declination. The agreement with the table on p. 10 of Publication XIV. for Greenwich 1872, was so close that I deemed the adoption of the latter to be entirely justifiable.

We have, then, in the table for each star, the number of observations and the deviation of each authority, after reduction to the Pulkowa system, from AUWERS's place. The inspection of the residuals seems to show in most cases a reasonably good confirmation of the corrections indicated by the almucantar observations, the testing of which was, indeed, the primary object of the investigation.

Thus, if we combine the data to form two epochs, one based on the Pulkowa observations and Greenwich 1861, the other on the later authorities — adopting AUWERS's weights where possible, and an analogous scale of weights for the later observations — we get for the *Hauptsterne* the following corrections to the right-ascension and proper-motion of the Fundamental Catalogue.

Star no.	Correction Fundamental Catalogue			1885.0 Comp.	Almuc.
	s	s		s	s
137	+0.148	+0.0090	(t — 1875.0)	+0.238	+0.243
139	+0.037	0.0000	"	+0.037	+0.075
159	—0.077	—0.0034	"	—0.111	—0.135
162	—0.041	—0.0043	"	—0.084	—0.061
171	+0.026	+0.0007	"	+0.033	+0.098
203	—0.089	—0.0074	"	—0.163	—0.249
224	+0.057	+0.0044	"	+0.101	+0.118
226	—0.118	—0.0083	(t — 1875.0)	—0.201	—0.177
240	—0.019	—0.0012	"	—0.031	—0.084
268	+0.028	+0.0017	"	+0.045	+0.057
302	+0.058	+0.0046	"	+0.104	+0.142
303	+0.021	+0.0013	"	+0.034	+0.062

In the last two columns are inserted the computed value of these corrections for 1885.0, and, for comparison, the observed values indicated by the almucantar observations alone.

It is interesting to compare the corrections so derived with the standard places adopted in the various ephemerides. Accordingly, I give the following table showing the deviations of the American Ephemeris, *Connaissance des Temps* and *Berliner Jahrbuch*, for the current year, 1887, from the above corrected places; after applying the systematic differences between these various standard systems, as investigated by Dr. AUWERS in the appendix to the *Jahrbuch* for 1884.

Star	Correction for 1887 to the Amer. Ephem.	Conn. d. Temps	Berl. Jahrb.
	s	s	s
1 H *Draconis*	—0.083		+0.256
λ *Draconis*	+0.043	+0.167	—0.093
κ *Draconis*	—0.194		+0.034
γ *Ursae Minoris*	—0.069	—0.412	—0.178
τ *Herculis*	+0.026		+0.110
η *Draconis*	—0.140	—0.578	—0.218
β *Draconis*	—0.044	+0.073	—0.033
γ *Lyrae*	+0.030	—0.020	+0.048
61 *Cygni* (pr.)	+0.058	+0.145	+0.113
ζ *Cygni*	+0.067	+0.033	+0.037

Of the polars it is to be remarked that GOULD's places, although the epoch of their formation antedates that of the other authorities, still hold in the most satisfactory manner. They give decidedly smaller corrections except in the case of κ *Draconis*. The comparison has not been extended to the Nautical Almanac, because its right-ascensions have been generally modified since 1883, when AUWERS's discussion of systematic differences was made. Only five of the stars were therein contained.

Cambridge, 1887 *March* 26.

RING-MICROMETER OBSERVATIONS OF COMET 1886 VIII.

MADE AT THE DUDLEY OBSERVATORY

BY H. V. EGBERT.

Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for
h m s			m s	′ ″	h m s	° ′ ″		
March 20 9 50 53	1	12	—2 14.93	—4 51.8	22 20 23.18	+56 32 35.7	9.094	0.937
26 9 8 17	2	14	—0 51.15	+5 17.2	22 47 3.26	+58 45 35.9	9.467	0.920

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	22 22 39.45	—1.34	56 37 35.0	—7.5	Krueger, Zones 30 and 202
2	22 47 55.78	—1.37	58 40 26.8	—8.1	Krueger, Zones 335 and 391

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RING-MICROMETER OBSERVATIONS OF COMET 1887 *d* (*Barnard, Feb. 16*)

MADE AT THE DUDLEY OBSERVATORY

BY LEWIS BOSS.

1887	Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	' "	h m s	° ' "		
Feb. 19	9 20 11	1	3	+4 58.6	+5 1	6 54 18.1	— 2 34 56	8.669	0.796
22	8 34 57	2	3	—2 47.4	—3 37	5 55 56.3	+ 9 31 39	8.975	0.690
22	9 20 19	3	5	—0 46.9	+0 14	5 55 23.7	+ 9 38 49	9.251	0.689
25	11 35 34	4	7	—2 18.1	+2 11	5 11 4.6	+18 7 14	9.636	0.702
25	11 50 5	5	5	+1 52.8	+5 21	5 10 55.9	+18 8 49	9.645	0.711

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ' "	"	
1	6 49 18.73	+0.82	— 2 39 42.1	—15.1	Cordoba and Karlsruhe
2	5 58 43.19	+0.55	+ 9 35 27.7	—11.8	Albany Transit-Circle
3	5 56 10.04	+0.54	+ 9 38 46.5	—11.8	μ *Orionis*
4	5 13 22.44	+0.28	+18 5 11.7	— 8.7	Weisse's Bessel, 319
5	5 9 2.82	+0.25	+18 3 37.0	— 8.6	Weisse's Bessel, 185

NOTES.

The observations of February 19 and February 22, were made in great haste, as opportunity offered through breaks in the clouds. The placing of the objects in the ring was not always the most favorable for accurate differences of declination. At the observation of February 25, this comet appeared to me to be at least three times as bright as the Finlay comet, which I had observed on the same evening. A part of the comparisons in the first set of Feb. 25 was made after those of the second set. The computed values of log $p\Delta$ in this case correspond to the mean values of that quantity, rather than to the mean of the times.

NOTE ON COMET 1886*e* (*FINLAY.*)

From a letter of Prof. Lewis Boss to the Editor.

My last observation of the Finlay Comet was made on the evening of Feb. 25, when I compared it with Weisse III. 655, with this resulting comet-position:

	Albany M.T.	App. α	App. δ
1887 Feb. 25	$9^h\ 34^m\ 28^s$	$3^h\ 34^m\ 31^s.4$	$+21°\ 28'\ 47''$

This is the mean of eight ring-micrometer determinations (13-inch equatorial), and gives as corrections to the ephemeris published in No. 150 of the *Astr. Journal:* $\Delta\alpha = +7^s.0$, $\Delta\delta = +19''$. On the occasion of this observation the atmosphere appeared to me to be remarkably pure and quiet, yet the comet was so faint that I was not always able to see it continuously across the field of view. As the comet on March 11 is less than two-thirds its brightness on Feb. 25, it does not appear to me worth while to extend the ephemeris. Should others desire to do so they are cautioned to omit the negative sign in connection with the logarithms contained in the equations of heliocentric coordinates, p. 43, No. 150 *Astr. Journal.*

S HYDRAE 1885.

BY EDWIN F. SAWYER.

This star was observed on twenty-one evenings, from March 17 to May 16. When first seen, on March 17, *S* was 3 steps > DM. 3°,2095, and 5 steps < DM. 3°,2093, or about $8^M.6$. The increase of light, although uniform, was not very rapid. A maximum was passed on April 2, the maximum brightness being 5+ steps > DM. 3°,2095, and 3 steps > DM. 3°,2093, or $8^M.2$. The decrease of light was slow and uniform, and when last observed, on May 16, *S* was 4 steps > DM. 3°,2081 = DM. 3°,2076, and 4 steps < DM. 3°,2088, or $8^M.8$.

Cambridgeport, 1887 *April* 4.

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THE VARIABLE STAR *F.10 SAGITTAE.*

S 714?

$19^h\ 49^m\ 25^s$, $+16^\circ\ 15'.4$ (1855.0).

By WM. MAXWELL REED.

From a two months' series of observations, the following maxima and minima were deduced by means of ARGELANDER's method and a light-curve. They have been compared with Mr. CHANDLER's elements of this star, published in the *Astr. Nachr.*, no. 2749, p. 217.

The mean correction for the maxima by weights is thus $-0^d.32$, with a probable error of $\pm 0^d.26$.

This deviation of $-0^d.32$ corresponds to a correction of the assumed period by $-1^m.05$; but for the amount of the probable error, the reality of such a correction may be regarded as doubtful, to be settled by future observations. It will be noticed that the above minima occur, without exception, before the assumed time. It is therefore likely that the period of increase is about four days.

Cambridge, 1887 *January* 10.

OBSERVED MAXIMA.

E	Camb. M.T. d	Wt.	O—C d
429	1886 Oct. 20.97	1	+0.99
431	Nov. 4.45	1	—1.30
432	14.31	1	+0.18
434	29.65	2	—1.24
435	Dec. 9.31	1	+0.03
436	17.29	1	—1.39
437	26.72	2	+0.70

OBSERVED MINIMA.

E	Camb. M.T. d	Wt.	O—C d
429	1886 Oct. 24.38	3	—0.98
433	Nov. 26.30	1	—1.59
435	Dec. 13.23	1	—0.43
436	20.88	1	—2.16
437	29.70	1	—1.70

ELEMENTS AND EPHEMERIS OF COMET 1887 *b* (*Brooks, Jan. 23*)

By LEWIS BOSS.

On March 12, I obtained this position of BROOKS's Comet, using the filar-micrometer:

Albany M.T.	App. α	App. δ
$8^h\ 9^m\ 8^s$	$3^h\ 55^m\ 59^s.81$	$+45^\circ\ 4'\ 57''.2$

The star of comparison is WEISSE's 1303. Combining this with an Albany observation of January 24, and with a position for 1887.0 derived from observations at Dresden, Göttingen, Hamburg and Kiel, on February 15

Greenw. M.T.	Corr. α	Corr. δ
$12^h\ 38^m\ 39^s$	$2^h\ 4^m\ 4^s.51$	$71^\circ\ 53'\ 1''.4$

the elements here given were derived. The positions were reduced to the mean equinox of 1887.0, and by means of the elements of this comet, published in No. 152 of this *Journal*, were also freed from the effects of parallax and aberration. The new elements are these:

$$T = 1887 \text{ March } 16.9819 \text{ Greenw. M.T.}$$
$$\left.\begin{aligned}\omega &= 159^\circ\ 9'\ 0''\\ \Omega &= 279\ 49\ 58\\ i &= 104\ 18\ 19\end{aligned}\right\}1887.0$$
$$\log q = 0.213070$$

The representation of the middle place is (C—O):

$$\Delta\lambda \cos\beta = +9''.0; \quad \Delta\beta = -4''.1$$

These residuals could have been made smaller by a repetition of the calculation with an improved ratio of the geocentric distances; and it consequently appears that the orbit of this comet does not materially differ from the parabolic form. It is not likely that the comet can be followed after the new moon at the end of April, chiefly because of its lessening elongation from the sun.

Dudley Observatory, 1887 *March* 15.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1887	App. α h m s	App. δ ° ″	log Δ	Light
March 21	4 13 12	+37 52.1	0.2348	0.8
23	16 34	36 26.4	0.2438	
25	19 50	35 4.3	0.2527	0.7
27	22 58	33 45.6	0.2615	
29	26 1	32 30.1	0.2702	
31	28 58	31 17.7	0.2788	
April 2	31 51	30 8.2	0.2872	0.6
4	34 40	29 1.5	0.2955	
6	37 24	27 57.2	0.3035	
8	40 5	26 55.3	0.3114	
10	42 43	25 55.7	0.3191	0.5
12	45 18	24 58.3	0.3266	
14	47 50	24 2.8	0.3340	
16	50 20	23 9.0	0.3411	
18	52 48	22 16.9	0.3480	
20	55 14	21 26.4	0.3548	
22	4 57 39	20 37.5	0.3613	0.4
24	5 0 1	19 49.9	0.3676	
26	2 22	19 3.6	0.3737	
28	4 41	18 18.4	0.3797	
30	5 6 59	+17 34.3	0.3854	0.3

The brightness at January 24 is taken as unity.

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OBSERVATIONS OF *SAPPHO* (80), NEAR OPPOSITION,

MADE AT THE WASHBURN OBSERVATORY, MADISON, WIS.

(Communicated by Prof. JOHN E. DAVIES, in charge of the Observatory.)

1887 Madison M.T.		*	No. Comp.	(80) — * $\Delta\alpha$	(80) — * $\Delta\delta$	(80)'s apparent α	(80)'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obsv'r
	h m s			m s	′ ″	h m s	° ′ ″			
Jan. 14	12 14 21	1	10	+1 4.21	—7 6.30	6 58 7.75	+9 4 6.5	9.0000	0.6920	M.U.
14	12 58 51	1	6	+1 2.17	—7 0.67	6 58 5.71	+9 4 12.1	9.2648	0.6972	J.E.D.
17	12 38 31	1	20	—1 58.79	—0 23.70	6 55 4.76	+9 10 48.8	9.2304	0.6955	M.U.
20	10 55 3	2	6	—4 51.23	+0 17.67	6 52 17.03	+9 18 12.0	7.7782	0.6866	M.U.
20	11 52 36	2	5	—4 53.47	+0 24.23	6 52 14.79	+9 18 18.5	9.0531	0.6893	J.E.D.
25	10 28 3	3	9	+2 33.02	—1 17.97	6 47 57.64	+9 32 53.4	7.3000	0.6848	M.U.
26	10 6 28	3	1	+1 46.30	+1 50.87	6 47 10.92	+9 36 2.2	n8.5051	0.6848	M.U.
28	9 42 3	3	10	+0 16.54	+8 18.60	6 45 41.14	+9 42 29.9	n7.7559	0.6839	A M.L.
28	10 10 51	3	15	+0 15.54	+8 24.15	6 45 40.14	+9 42 35.4	n7.6990	0.6830	M.U.

Adopted Mean Places for 1887.0 of Comparison-Stars.

Date 1887	*	α	Red. to app. place	δ	Red. to app. place	
		h m s	s	° ′ ″	″	
January 14	1	6 57 2.60	+0.94	+9 11 23.1	—10.4	⅓(Lalande + 2d Radcliffe Cat. + Glasgow Cat.)
17	1	6 57 2.60	+0.95	+9 11 23.1	—10.6	" " " " "
20	2	6 57 7.29	+0.97	+9 18 5.2	—10.9	⅓(Gr. VII. + 2d Radcliffe Cat. + Glasgow Cat.)
25	3	6 45 23.66	+0.96	+9 34 22.4	—11.1	½(Weisse's Bessel + Glasgow Cat.)
26	3	6 45 23.66	+0.96	+9 34 22.4	—11.1	" " " "
28	3	6 45 23.66	+0.94	+9 34 22.4	—11.2	" " " "

The above observations of *Sappho* (80) with the filar-micrometer of the 15½ inch equatorial, of the Washburn Observatory, were made in answer to a request to me from Mr. S. W. BURNHAM, of Chicago, who transmitted to me the following letter received by him from Mr. ROBERT BRYANT, of the Royal Astronomical Society, London.

"In 1889 there will be a favorable opposition of *Sappho* for the determination of the Solar parallax, and for this purpose I am engaged in determining its orbit. There are, however, few observations of the planet. There were none published between 1872 and 1882, and none since 1882. May I ask that under these circumstances you will assist me by making such observations of (80) as you can next January; more especially as the planet, on account of its faintness, will be beyond the reach of all except the finest instruments, at least for accurate observation." Accompanying this letter was an ephemeris of the planet for the period from January 7 to February 6, 1887.

Mr. BURNHAM wrote that it would be impossible for him to make the observations and requested me if possible to do so. A run of unfavorable weather at the time of the receipt of Mr. B.'s request, and subsequent bright moonlight, prevented the beginning of observations until January 14, since which time the planet has been observed on every clear night.

The comparison-stars, numbered above as one, two, three, were found in Lalande, the 2d Radcliffe Cat., Greenwich 7-Year Cat., Weisse's Bessel, and the last Glasgow Cat. In the latter catalogue all three stars are found and are numbers 1734, 1735 and 1670 for stars one, two and three, respectively. The observers were M. UPDEGRAFF, Miss A. M. LAMB and myself.

OBSERVATIONS OF COMET 1887 *b* (*BROOKS*)

MADE WITH THE 9.6 INCH EQUATORIAL AT THE U.S. NAVAL OBSERVATORY

BY PROF. E. FRISBY.

(Communicated by the Superintendent.)

Washington M.T. 1887.0		*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
March 11	8 30 8.5	1	20 , 4	+2 58.22	+0 16.1	3 53 51.54	+47 57 10.3	9.746	0.268
12	8 46 52.0	2	20 , 4	—4 33.52	+4 20.8	3 56 6.23	+45 3 2.6	9.764	0.229

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Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	3 50 53.71	—0.39	+45 56 53.3	+0.9	Rümker, N.F. 2024
2	4 0 40.08	—0.33	+44 58 40.8	+0.9	Weisse III. 1249

ELEMENTS AND EPHEMERIS OF COMET 1887 *c* = 1886 VIII.

By H. V. EGBERT.

The elements herewith transmitted are based upon the observations given below. For the middle place the details of the observation were kindly furnished by Prof. Frisby.

The comparison-star having a proper-motion, I have adopted, as the place for 1887.0, $\alpha = 20^h\ 28^m\ 52^s.19$; $\delta = 41°\ 29'\ 56''.5$, with a proper-motion of $-0^s.017$ and $+0''.45$. The other places were determined by myself; the first with a filar and the last a ring-micrometer. On March 20, the theoretical light being 0.5, the comet was still easily observed.

1887 Greenw. M.T.		App. α	App. δ
Jan. 24	$22^h\ 59^m\ 11^s$	$19^h\ 10^m\ 19^s.99$	+25° 58′ 14″.3
Feb. 18	22 20 39	20 25 24 .14	41 24 24 .1
Mar. 20	14 45 52	22 20 23 .18	56 32 35 .7

Elements.

$$T = 1886 \text{ Nov. } 28.37512 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= \ \ 31°\ 53'\ 16'' \\ \Omega &= 258\ \ 11\ \ 58 \\ i &= \ \ 85\ \ 35\ \ 18 \end{aligned}\right\} \text{M. Eq. } 1887.0$$

$$\log q = 0.170274$$

C—O: $\Delta\lambda \cos\beta = -2''.6$, $\Delta\beta = +7\ .6$

Heliocentric Coordinates.

$$x = r\,[9.338309]\sin(v + 322°\ 6'\ 2''.7)$$
$$y = r\,[9.994619]\sin(v + 277\ \ 16\ \ 50\ .7)$$
$$z = r\,[9.994942]\sin(v + \ \ 8\ \ 40\ \ 25\ .8)$$

Ephemeris for Greenwich Midnight.

1887	α	δ	log Δ	Light
	h m s	° ′		
Mar. 30	23 5 6	+60 2.9	0.4095	0.41
Apr. 3	23 23 48	61 13.2	0.4185	0.38
7	23 42 45	62 15.2	0.4276	0.35
11	0 1 50	63 9.3	0.4367	0.33
15	0 20 57	63 55.8	0.4458	0.30
19	0 40 0	64 35.2	0.4549	0.28
23	0 58 52	65 8.0	0.4638	0.26
27	1 17 26	65 34.7	0.4725	0.24
May 1	1 35 36	+65 55.9	0.4811	0.23

Dudley Observatory, Albany, 1887 *March* 23.

ON THE NEW VARIABLE *U AQUILAE*. 6984

$19^h\ 22^m\ 38^s$; $-7°\ 17'.9$ (1875.0)

By EDWIN F. SAWYER.

The following provisional elements have been determined for the above variable, from a discussion of my observations extending from 1886 September 21 to December 20 (the discovery having been communicated in No. 147 of this *Journal*).

M = 1886 September $20^d.01$ (Camb. M.T.) $+7^d.0$ E.

Duration of increase = $2^d.5$

" " decrease = 4 .5

Limits of variation { Maximum, $L = 14.9 = 6^M.3$; Minimum, $L = 4.6 = 7\ .3$

From the limited series of observations the following first approximation to the light-curve is obtained:

Before Maximum.

$-3^d.0$	$L = 5.0$	$-1^d.5$	$L = 5.6$
—2.5	$L = 4.6$	—1.0	$L = 9.0$
—2.0	$L = 4.7$	—0.5	$L = 14.0$

After Maximum.

$+0^d.5$	$L = 14.2$	$+3^d.0$	$L = 7.4$
+1.0	$L = 12.4$	+3.5	$L = 6.4$
+1.5	$L = 10.0$	+4.0	$L = 5.0$
+2.0	$L = 8.8$	+4.5	$L = 4.6$
+2.5	$L = 8.2$	+5.0	$L = 4.7$

Using values of $L > 9$ for determining maxima, and the others for determining minima, and applying to the times of each observation of the variable the correction indicated by the comparison of its observed light with the mean light-curve readings given above, the following observed times of maxima and minima have been determined. The number of observations used in deducing each phase is employed in denoting the weight of the observation.

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Observed Maxima.

E	Camb. M.T.	Wt.	O−C (d)
0	1886 Sept. 19.88	1	−0.16
3	Oct. 17.97	1	−0.07
4	23.89	2	−1.15
5	Nov. 1.00	2	−0.04
6	8.20	3	+0.16
7	15.11	2	+0.07
8	22.43	3	+0.39
9	29.62	2	+0.58
11	Dec. 13.11	1	+0.07
12	19.64	1	−0.40

Observed Minima.

E	Camb. M.T.	Wt.	O−C (d)
0	1886 Oct. 23.57	2	+0.42
2	Nov. 6.06	2	−0.09
3	13.00	1	−0.15
4	19.81	2	−0.34
5	26.84	2	+0.31
6	Dec. 4.33	2	+0.18
8	18.52	1	+0.37

The light-curve exhibits a uniform and rather rapid increase, and a slow and somewhat irregular decrease.

Cambridgeport, 1887 *March* 29.

TWO HUNDRED SIXTY-FIFTH ASTEROID.

This was discovered on the night of February 25th, by Dr. J. Palisa, at Vienna, and the positions determined on the 25th and 27th were communicated by telegraph.

The *Astronomische Nachrichten*, No. 2776, contains an additional position observed at Hamburg, Feb. 28. The series of observations is as follows:—

1887	Local M.T.	α	δ	
	h m s	h m s	° ′ ″	
Feb. 25	12 33 5	10 31 43.55	+7 49 45.4	Vienna
	13 55 59	31 37.90	49 10.1	"
27	10 10 56	10 28 33.83	+7 32 16.5	"
28	11 26 7	10 26 47.67	+7 22 21.5	Hamburg

Magnitude = $12^{M}.5$.

CORRIGENDA.

No 150. p. 43. Omit the *n*s prefixed to the logarithms in the equations of the coordinates for 1886.0 and 1887.0.

p. 47. Ephemeris of Comet of Finlay: Transfer the value of the "App. α" opposite Feb. 25 to March 3, and raise all other values one line; over the figures in the column "Hourly Motion," for ′ read ″; in column "log Δ," opposite March 3, for 0.900574, read 0.200574.

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THE

ASTRONOMICAL JOURNAL.

No. 156.

VOL. VII. BOSTON, 1887 MAY 20. NO. 12.

ON THE PARALLAX OF α *TAURI*,

BY PROF. A. HALL.

(Communicated by Captain R. L. PHYTHIAN, Superintendent Naval Observatory.)

Director OTTO von STRUVE, of the Pulkowa Observatory, has published recently a determination of the parallax of this star and finds the result

$$\pi = +0''.516 \quad \pm 0''.057.$$

This value has been found from the angles of position and the distances of a companion of the 11th magnitude, and the observations extend from December 1, 1850, to March 18, 1857. These observations are not very numerous, but the excellent agreement between the values of the parallax found from the angles and the distances gives great weight to this determination, and justifies the assertion of STRUVE that α *Tauri* is one of the stars nearest our solar system.

On beginning observations of *Saturn* in October, 1886, I found that it would require but little more time to make some measures of α *Tauri* and its companion; and I was curious to see how my result for parallax, derived from similar observations of the same stars, would agree with that found by STRUVE. The following are my observations of α *Tauri* and its companion. Each observation consists of four settings of the position-circle, and of four measures of the double distance. The magnifying power was 383. When the atmosphere was in a good condition the image of the bright star appeared as a small disk surrounded by streamers of light, and this disk could be bisected in a satisfactory manner; but on a few nights the disk was lost in a blaze of light, and the bisections were uncertain. On the whole I think the observations of the angles and the distances are fair.

Date	Sid. Time	p	s	Wt.	Temp.	Notes
	h m	°	"		°	
1886 Oct. 2	4 10	34.487	116.25	2	48.0	blazing images
3	4 45	34.550	116.05	3	45.0	
4	4 52	34.585	116.09	2	49.0	
5	4 55	34.605	115.79	2	54.5	hazy and blazing images
6	5 9	34.348	116.42	2	50.0	blazing images
7	4 55	34.380	116.39	3	50.5	
8	5 13	34.542	116.20	3	51.2	
9	4 40	34.500	116.13	3	54.8	
10	5 15	34.510	116.24	3	55.5	

Date	Sid. Time	p	s	Wt.	Temp.	Notes
	h m	°	"		°	
1886 Oct. 11	5 28	34.480	116.17	3	56.2	
1887 Feb. 27	5 43	34.500	116.17	3	29.5	windy
28	5 20	34.500	116.38	2	30.0	
Mar. 1	5 20	34.575	116.11	3	41.0	
8	5 39	34.625	116.22	3	49.0	
10	5 46	34.775	116.54	3	47.0	
11	5 49	34.550	116.47	2	41.8	
12	5 55	34.650	116.20	2	45.5	
13	6 3	34.600	116.11	2	47.5	
14	6 5	34.475	116.41	2	36.0	windy
15	6 10	34.700	116.27	3	47.3	cloudy

These observations require corrections for differential refraction, and reduction to the epoch 1887.0. The first column of the following table gives the date in Greenwich M.T. for interpolating the longitude and radius-vector of the sun. The next column gives the correction Δp for differential refraction. For the reduction on account of the proper-motion of α *Tauri*, I have assumed the annual variations in the angle and distance of the companion to be

$$\delta p = -2'.0 \quad : \quad \delta s = +0''.150,$$

and this reduction is given under the head $\Delta\mu$. The reduction for precession, nutation and aberration has been computed from the formulas given in the last section of BRÜNNOW'S Astronomy. This quantity is given in the columns Δp and Δs; and finally $\Delta\tau$ is the reduction of the distances to the temperature 50° Fahr.

The coefficients for the annual parallax have been computed by the formulas of BESSEL, *Astronomische Nachrichten*, Band 16, p. 83. As there appears to be a misprint in the *Nachrichten*, the formulas are repeated here. Denoting by α and δ the right ascension and declination of the point midway between the stars, by ε the obliquity of the ecliptic, and by p and s the angle of position and the distance, we compute the four auxiliary quantities:

$$m \sin M = -\cos\varepsilon \cos\alpha \sin p + \cos\varepsilon \sin\alpha \sin\delta \cos p - \sin\varepsilon \cos\delta \cos p$$
$$m \cos M = \sin\delta \cos\alpha \cos p + \sin\alpha \sin p$$
$$m' \sin M' = \tfrac{1}{s}[-\cos\varepsilon \cos\alpha \cos p - \cos\varepsilon \sin\alpha \sin\delta \sin p + \sin\varepsilon \cos\delta \sin p]$$
$$m' \cos M' = \tfrac{1}{s}[-\sin\delta \cos\alpha \sin p + \sin\alpha \cos p]$$

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If π be the parallax of the star, θ the longitude of the sun, and R its radius vector, the expressions for the parallax in distance and angle of position are

$$ds = \pi\, Rm \cos(\theta - M)$$
$$dp = \pi\, Rm' \cos(\theta - M')$$

For the present case we have

$$M = 332^\circ\ 26'.9 \qquad \log m = 9.83921$$
$$M' = 343\ \ 22.0 \qquad \log sm' = 9.86303$$

TABLE OF REDUCTIONS.

Date	ANGLE $\Delta\rho$	$\Delta\mu$	Δp	p_0	DISTANCE $\Delta\rho$	$\Delta\mu$	Δs	$\Delta\tau$	s_0
	°	°	°	°	"	"	"	"	"
1886 Oct. 2.8547	+0.001	—0.008	+0.001	34.479	+0.035	+0.037	+0.009	+0.001	116.332
3.8761	0.001	0.008	0.001	.542	0.037	0.037	0.009	+0.002	116.135
4.8782	0.001	0.008	0.001	.577	0.037	0.037	0.009	0.000	116.173
5.8775	0.001	0.008	0.001	.597	0.037	0.036	0.009	—0.002	115.870
6.8844	0.002	0.008	0.001	.339	0.039	0.036	0.009	0.000	116.504
7.8719	0.001	0.008	0.001	.372	0.038	0.035	0.009	0.000	116.472
8.8817	0.002	0.007	0.001	.534	0.039	0.035	0.009	—0.001	116.282
9.8560	0.001	0.007	0.001	.493	0.037	0.034	0.009	0.002	116.208
10.8775	0.002	0.007	0.001	.502	0.039	0.034	0.009	0.003	116.319
11.8837	0.001	—0.007	+0.001	.473	0.040	+0.033	+0.009	—0.003	116.249
1887 Feb. 27.5146	0.001	+0.005	—0.001	.503	0.041	—0.024	—0.012	+0.010	116.185
28.4959	0.002	0.005	0.001	.502	0.039	0.024	0.011	0.010	116.394
Mar. 1.4931	0.002	0.005	0.001	.577	0.039	0.025	0.011	+0.004	116.117
8.4876	0.001	0.006	0.001	.629	0.041	0.028	0.011	0.000	116.222
10.4869	0.001	0.006	0.001	.779	0.042	0.029	0.012	+0.001	116.542
11.4862	0.001	0.006	0.001	.554	0.042	0.029	0.012	0.004	116.475
12.4876	0.001	0.006	—0.001	.654	0.043	0.029	0.012	0.002	116.204
13.4903	0.002	0.007	0.000	.605	0.044	0.030	0.011	0.001	116.114
14.4890	0.002	0.007	0.000	.480	0.044	0.030	0.011	0.007	116.420
15.4897	+0.002	+0.007	0.000	34.705	+0.045	—0.031	—0.011	+0.001	116.274

In forming equations of condition it is a general rule to introduce corrections to the constants assumed in the reductions, but here I omit the differential correction to the constant of aberration, since there seems to be no physical reason why this constant should be different for the two stars. The corrections to the assumed values of the proper-motions are omitted because the proper-motion of *α Tauri* is well known, and the observations extend over such a short time that in the solution these corrections would have no weight. The values of the angle and distance have been assumed for 1887.0 to be

$$p = 34^\circ.542, \qquad s = 116''.273.$$

If x be the correction to the assumed angle or distance, and y the parallax, we have the following equations of condition.

No.	ANGLE Equation	Residual	DISTANCE Equation	Residual
	"	"	"	"
1	x —0.6518 y +0.128 = 0	+0.020	x —0.5471 y —0.059 = 0	—0.080
2	0.6457 +0.000 = 0	—0.107	0.5394 +0.138 = 0	+0.118
3	0.6396 —0.071 = 0	—0.177	0.5317 0.100 = 0	+0.080
4	0.6333 —0.112 = 0	—0.217	0.5239 +0.403 = 0	+0.384
5	0.6267 +0.412 = 0	+0.308	0.5159 —0.231 = 0	—0.250
6	0.6201 0.345 = 0	+0.242	0.5079 0.199 = 0	—0.218
7	0.6132 0.016 = 0	—0.086	0.4995 —0.009 = 0	—0.027
8	0.6063 0.099 = 0	—0.002	0.4913 +0.065 = 0	+0.047
9	0.5989 0.081 = 0	—0.018	0.4826 —0.046 = 0	—0.064
10	—0.5915 0.140 = 0	+0.042	—0.4738 +0.024 = 0	+0.006
11	+0.7210 +0.079 = 0	+0.194	+0.6797 +0.088 = 0	+0.111
12	0.7219 —0.081 = 0	+0.196	0.6784 —0.121 = 0	—0.098
13	0.7227 0.071 = 0	+0.044	0.6768 +0.156 = 0	+0.179
14	0.7221 0.177 = 0	—0.062	0.6604 +0.051 = 0	+0.073
15	0.7199 0.481 = 0	—0.366	0.6539 —0.269 = 0	—0.247
16	0.7186 0.024 = 0	+0.091	0.6504 —0.202 = 0	—0.180
17	0.7170 0.227 = 0	—0.112	0.6466 +0.069 = 0	+0.091
18	0.7151 —0.128 = 0	—0.014	0.6427 +0.159 = 0	+0.180
19	0.7131 +0.126 = 0	+0.240	0.6386 —0.147 = 0	—0.126
20	+0.7108 —0.331 = 0	—0.217	+0.6342 —0.001 = 0	+0.020

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The notes for a few of the observations would justify a diminution of the weights, especially on October 5, but in reducing to the normals equal weight has been assigned to each of the observations. In this way the normal equations and their solutions are as follows:

ANGLE.

$$+20.0000\,x \quad +0.9551\,y \quad -0''.1150 = 0$$
$$+\ 0.9551\,x \quad +9.0399\,y \quad -1\ .4678 = 0$$
$$x = -0''.002 \pm 0''.0275; \qquad [nn.2] = 0''.5951$$
$$y = +0\ .163 \pm 0\ .0409; \qquad \Sigma pv^2 \ = 0\ .5951$$

The probable error of a single equation is $\pm 0''.123$.

DISTANCE.

$$+20.0000\,x \quad +1.4514\,y \quad -0''.0310 = 0$$
$$+\ 1.4514\,x \quad +6.9282\,y \quad -0\ .2404 = 0$$
$$x = -0''.001 \pm 0''.0253; \qquad [nn.2] = 0''.5007$$
$$y = +0\ .035 \pm 0\ .0431; \qquad \Sigma pv^2 \ = 0\ .5006$$

The probable error of a single equation is $\pm 0''.112$.

Washington, 1887 *March* 30.

The mean value of the parallax of *α Tauri* from these observations is, therefore,

$$\pi = +0''.102 \pm 0.0296.$$

The values of the angle of position and the distance of the companion for 1887.0 are

$$p = 34^\circ.541; \qquad s = 116''.272.$$

It will be noticed that the resulting value of the parallax is only one-fifth that found by STRUVE. The residuals and the probable error of a single observation are not larger than what might be expected when we consider the brightness of the principal star. The observations were all made near the meridian, the range of the temperature was small, and the conditions generally were as good as are likely to occur. Although the observations are not numerous, I think my result would not be essentially changed by continuing them.

I am indebted to Lieut. W. H. ALLEN, U.S.N., for assistance in the reductions.

THE GREAT SOUTHERN COMET, (*1887a*)

By JOHN M. THOME.

As I advised by telegram, dated Cordoba, January 21, this comet had already been detected upon the evening of the 18th, but it was then so faint and illusory in the twilight and denser atmosphere near the horizon, that I only suspected its nature. The following night was cloudy, but upon the 20th it had declared itself; eluding, however, satisfactory observation in the long twilight, and clouds which formed in that part of the sky soon shut it out altogether.

Upon the 21st it at once became evident that I had to deal with a comet which was, in effect, all tail; the head being much the fainter part of the object, and its place occupied apparently by a chaos of volatilization whose dimensions I could not determine, but which was at least twice the diameter of the field of view (15′) of our equatorial, and very thin and without nucleus or condensation of any kind. After various attempts at determining its coordinates, I adopted the plan of moving the telescope along the axis of the tail, until reaching a point beyond which nothing of a nebulous character could be distinguished, and determining its position. These points were, approximately, half a degree in advance of the true center of the nebulosity and nearly in its axis. In every case I found a star in this place, and was able to identify it in our catalogues; and the accompanying positions are the reduced places of those stars.

The tail steadily grew in apparent brightness and length, as the comet increased its distance from the horizon, until January 25th, when it became evident that it had been fading from the first, and the head had now become almost invisible in the telescope. By the 27th, with the added moonlight, it had diminished to such a degree that only the crudest approximations to its position could be obtained; and after the moon had passed the full, not a trace could anywhere be found.

From the 22d to the 25th the comet was a beautiful sight to the naked eye — a narrow, straight, sharply defined, graceful tail, over 40° long, shining with a soft, starry light against the dark sky; beginning, apparently, without a head, and gradually widening and fading as it extended upwards. A band of its dimensions, cut from the heart of the milky way in the neighborhood of *ρ Puppis* and transferred to its quarter of the sky, would very nearly represent its brightness, except in the anterior part — the apparent beginning — where it was brighter.

The determinations of its position, and my notes made at the time of observation, are as follows:

FOR THE TAIL. (Taken from map No. 14 of U.A.)

Jan. 20		It closely follows *θ Indi*, extending from the horizon, and visible at intervals through twilight and haze for about 20° in length. Soon clouded over.
Jan. 21	$8^h\ 50^m$.	Extends on s. pr. side from G.C. 29273 to 2d beyond *δ Tucanae*. Extends on n. foll. side from G.C. 29273 to intersection of 22^h at 60°.
Jan. 22	$8^h\ 50^m$.	On s. pr. a straight line from comparison star to *ξ Tucanae*. On n. foll., a straight line from comparison star to *λ Tucanae*. Limit: the nubecula minor.

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Jan. 24	$8^h\ 50^m$.	On s. pr., a straight line to *δ Hydri*. On n. foll., a straight line to U.A. 46 *Hydri*. Limit: about 2° beyond.
Jan. 25	$8^h\ 50^m$.	On s. pr. side, a straight line from beginning to *β Reticuli*. On n. foll. side, a straight line from beginning to *κ Reticuli*.

FOR THE EXTREME ANTERIOR POINT OF THE COMETARY AXIS.

	h m	h m s	° ′	
Jan. 21	8 43	21 14 26	—43 53	G.C. 29273
22	8 48	21 32 16	45 5	G.C. 29623
24	8 46	22 8 18	47 20	Z.C. 231
25	8 33	22 35 21	48 46	G.C. 30901
27	9 38	23 28 38	—48 41	G.C. 31895*

*Very doubtful.

NOTES.

January 21. The appearance of the comet, in brilliancy and its general characteristics, is precisely the same as the one observed here in 1880. It has a long, straight, narrow tail, inclined to the vertical at about 15°. Searched carefully for a nucleus of some kind, but could find nothing resembling one, the comet seeming to end indefinitely — lose itself. Turned the telescope upon the brightest part of the tail, and moved it forward to the last visible extremity. The star Gen. Catal. 29273 occupied this position at $8^h\ 43^m$. Tail ends just beyond *α Tucanae*. Comet about 5° above the horizon.

January 22. Same general appearance as last night, but brighter. No nucleus or condensation of any kind found after protracted search. Begins with the star Gen. Catal. 29623 and extends in a straight line to the smaller cloud. The densest part of the tail seemed to be about 40^s following the star G.C. 29663, where it was, approximately, 20′ wide. No distinctive point could be found between these limits. Tail narrow and clearly defined, could be traced over 40°.

January 24. Again no distinctive point to be found. Observing as before, found the star Z.C. XXII. 231 at the beginning, and fixed the densest part of the tail at $22^h\ 9^m\ 8^s$, —48° 55′. Tail 41° long.

January 25. Comet fading rapidly; very difficult to fix upon the beginning, which is put at G.C. 30901.

January 27. Comet much fainter, but still easily visible to the naked eye. Almost impossible to distinguish between nebulous matter and haze in field of telescope. Begins with Gen. Catal. 31895.

From the observations of January 21, 22, and an interpolated position for January 23, I computed the following parabolic elements, referred to Greenwich mean time, apparent equinox, and uncorrected for aberration and parallax:

Greenw. M.T.	α (h m s)	δ (° ′)
Jan. 21.5396	21 14 26	—43 53
22.5436	21 32 0	45 5
23.5429	21 50 9	46 13

$$T = 1887 \text{ Jan. } 8.825 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \pi &= 189°\ 54' \\ \Omega &= 315\ \ 36 \\ i &= \ \ 65\ \ 25 \end{aligned}\right\} \text{App. Eq.}$$

$$\log q = 9.29360$$

Retrograde.

Cordoba, 1887 *March* 15.

ON THE ORBIT OF THE GREAT SOUTHERN COMET, 1887 *a*.

BY S. C. CHANDLER, JR.

The communication of the observations of Dr. THOME makes possible, for the first time, some calculations upon the orbit of this most remarkable comet, and I have therefore attempted to collect and discuss all the material available. The results of the computation are indeterminate and unsatisfactory to the last degree. Nevertheless, since it is likely that the information we now possess may receive no substantial additions, these results are here submitted, although I have little confidence that they represent the real orbit.

The difficulty in dealing with this case arises from a peculiarity for which there is no precedent in astronomical history, at least among the larger and brighter comets. The center of gravity of a comet's mass, whose motion according to the law of gravitation it is sought to define by calculation, is ordinarily assumed to be represented by the visible nucleus, or by the most condensed portion of the head. In rare instances, where disintegration of the nucleus takes place during the comet's apparition, as in the Great Comet of 1882, doubt will arise as to the true position of the center of gravity, sufficient to render futile any nice calculation of the eccentricity, but still not enough to prevent a very precise determination of the plane, and of the general form of the orbit, near the sun. But there is no criterion by which to define the center of gravity of an acephalous object like the present one, which is described as a ray or band about 40° long, as pale as the brighter parts of the Milky Way, narrower and somewhat brighter towards the end where the head ought to be; but, according to the concurrent testimony of all the observers, without condensation of any kind. From what can be gathered in the various accounts, the brightest portion of the tail was not at its anterior and narrowest point, where the coma would naturally be looked for. In the observation of such an object the ordinary methods of position-measurement fail, telescope and micrometer being alike useless.

In the first table following, I have collected all the data from which an idea of the path traversed by the comet can be formed. Even with the most careful reading of the published descriptions, the construction to be placed on them and the coordinates chosen for calculation will depend largely upon the judgement of the computer. In the conduct of this investigation I have had the advantage of consultation and discussion with Dr. GOULD, of the various points involved, and have relied largely upon his advice.

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Greenwich M.T. 1887	Observed Position. α	δ	p	Δα	Δδ	Assumed Position. α	δ	Place of Observation.
d	h m s	° ′	°	s	′	h m s	° ′	
Jan. 20.705	21 5 0	−42 34				21 5 0	−42 34	Melbourne.
21.538	21 14 26	43 53	157	+ 66	−28	21 15 32	44 21	Cordoba.
21.705	21 20 28	44 17				21 20 28	44 17	Melbourne.
22.317	21 30 4	45 48				21 30 4	45 48	Cape of G H.
22.542	21 32 16	45 5	155	+ 72	−27	21 33 28	45 32	Cordoba.
24.540	22 8 18	47 20	140	+114	−23	22 10 12	47 43	"
25.531	22 35 21	48 46	135	+128	−21	22 37 29	49 7	"
27.576	23 28 38	48 41	117	+162	−13	23 31 20	48 54	"
27.913	23 41 16	50 51				23 41 16	50 51	Windsor, N. S. W.
29.913	0 26 8	49 26				0 26 8	49 26	" "

The Greenwich mean times were estimated, for all except the Cordoba observations. The date of the second Melbourne position is assumed to have been a day earlier than that assigned in the cable dispatch, which is incompatible with the other facts. The positions for Melbourne and the Cape are those assigned in the dispatches. For the Windsor observations, I have assumed the place of the comet to be coincident with the stars σ and λ *Phoenicis*. For Cordoba, the column "Observed Position" contains the coordinates of the extreme anterior point of the cometary axis, determined as described by THOME. He has used these places in his computation of the orbit. He remarks, however, that they were about half a degree in advance of the true center of the nebulosity, and nearly in its axis. It would seem, therefore, that they might be modified with advantage by an appropriate correction. Accordingly, from the descriptions of the position of the tail, I have computed or measured the approximate position-angle, p, of its axis. Then, calling σ the apparent angular distance of the comet's center of gravity from the extremity of the axis, the coordinates of the former point will be found by adding

$$\Delta\alpha = \tfrac{1}{15}\,\sigma \sin p \sec \delta\,; \quad \Delta\delta = \sigma \cos p.$$

Assuming $\sigma = 30'$, we have the corrections given in the table, from which results the column headed "Assumed Position."

At first view TEBBUTT's position of the 27th (Greenwich date) might be thought to require a similar modification. He says that, although the star σ *Phoenicis* was not apparently surrounded by nebulosity, he took it at first to be the nucleus; but that, although the lower extremity of the cometary ray or beam was certainly in the immediate neighborhood of the star, he could not, after a most careful search, find the slightest condensation for observation. On mature reflection, however, I concluded to leave the position as it stands in the table. If we apply the amount of the comet's motion, according to either orbit hereafter given, in the elapsed interval between THOME's and TEBBUTT's observations on this evening, to the position given by the former as the extreme end of the axis, it will lie about two degrees north and half a degree preceding σ *Phoenicis*, and the tail will lie so that this star clears its south preceding edge. This is entirely consistent with TEBBUTT's description.

From the above data two distinct calculations of the orbit have been made. The first, from the "observed positions," is marked I.; the second, from the "assumed positions," is marked II. To the Melbourne and Cape observations was assigned the weight one, to those at Windsor one-half, and to those at Cordoba two, in the first calculation. In the second calculation the Cordoba weights were increased by unity.

	I.	II.
T (Greenw.)	1887 Jan. 9.080	Jan. 8.730
ω	173° 36′.2	174° 48′.6
☊	130 46 .2	132 48 .6
i	61 48 .9	57 52 .1
log q	8.30484	8.36280
C—O $\Delta\lambda\cos\beta$	+ 4′.1	−1′.2
$\Delta\beta$	−10 .7	+2 .3

These two sets of elements — the second of which I think should have the preference — do not materially differ, considering the extreme uncertainty of the observations. How great this uncertainty is, can best be appreciated by the following residuals, (O — C):

Place.	Date.	Obs'd Position Orbit I. Δα	Δδ	Assumed Posit. Orbit II. Δα	Δδ
	d	s	′	s	′
Melbourne	Jan. 20.705	+ 68	+23	+ 58	+28
Cordoba	21.538	−101	+14	− 39	− 8
Melbourne	21.705	+101	+ 5	+ 99	+10
Cape G.H.	22.317	+ 67	−42	+ 68	−36
Cordoba	22.542	− 36	+25	+ 38	+ 4
Cordoba	24.540	−250	+26	−136	+12
Cordoba	25.531	+ 7	−11	+126	−22
Cordoba	27.576	+ 57	+37	+110	+36
Windsor	27.913	+263	−95	+192	−83
Windsor	29.913	−312	−84	−464	−74

These elements are very unlike those of 1880 I, with which this comet was associated in the early dispatches from the Cape. In what manner this association arose does not yet clearly appear. It is hardly probable that it was an inference from direct calculation; but rather that it was a mere surmise, founded on the general similarity of the circum-

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stances of the apparition, and on the fact that the line of sight nearly intersected the orbit of 1880 I. In the *Science Observer*, Special Circular No. 74, published January 31, I gave a hypothetical ephemeris, using MEYER's elements of that comet,

$$\begin{aligned} \omega &= 77^\circ\ 53'.9 \\ \Omega &= 356\quad 16.7 \\ i &= 143\quad 7.8 \\ \log q &= 7.7714 \end{aligned}$$

and assuming for the perihelion-passage 1887 Jan. 11.0, Gr. M.T. If we compare the "observed positions" of the comet with this ephemeris, computing the necessary additional places, it will be found that the actual and hypothetical paths coincided within about a degree and a half during the entire apparition, over a geocentric arc of three and a half hours of right-ascension. Thus we have:

Gr. M.T.	Observed Position.		Hypoth. Ephemeris.	
1887	α	δ	α	δ
Jan. 20.705	21ʰ 5ᵐ.0	−42° 34′	20ʰ 58ᵐ.9	−43° 31′
21.538	21 14 .4	43 53	21 13 .1	44 57
21.705	21 20 .5	44 20	21 16 .1	45 14
22.317	21 30 .1	45 48	21 27 .4	46 12
22.542	21 32 .3	45 5	21 31 .6	43 33
24.540	22 8 .3	47 20	22 12 .9	49 3
25.531	22 35 .3	48 46	22 35 .0	49 54
27.536	23 28 .6	48 41	23 22 .2	50 42
27.913	23 41 .3	50 51	23 30 .0	50 48
29.913	0 26 .2	49 26	0 15 .0	50 6

This agreement naturally suggests the question whether the observations may not be reconciled with an orbit similar to those of the great comets of 1843, 1880, and 1882, by plausible assumptions as to the center of gravity of the comet's mass. It is not at all certain that the observers may not have been deceived as to the non-existence of a nucleus. It will be recollected that the comet of 1882, belonging to this group, appeared, two or three weeks after perihelion, to be surrounded by an outer envelope, the lines of which, beginning many degrees back of the nucleus, and gradually converging, extended forward several degrees beyond the coma. It there terminated in an ill-defined manner, forming an exterior false comet, as it were, with its head much in advance of the real one. If the diagrams published by HARTWIG, SCHMIDT, SAWYER, SCHWAB, BARNARD, and others, be collated with the accounts of the present comet, it does not seem a very violent supposition that a similar double envelope may have existed in this case, though of such slightly different density that the observers overlooked the nucleus by groping for it near the origin of the outer envelope, instead of far back in the axis, near that of the inner one.

From such superficial examination as I have been able to give, it is strongly doubted whether any such reconciliation as that suggested in the preceding paragraph can be effected. This examination was made in the following way. First, coordinates were computed from the orbit of 1880 I, for three normal dates, under the form

$$\left.\begin{array}{llll} \text{Jan. } 21.5 & 21^h\ 12^m.4\ -10^m.1\,x & -44^\circ\ 53' & +132'\,x \\ \quad 24.5 & 22\ 12\ .0\ -13\ .7\,x & \quad 49\ \ 1 & +110\,x \\ \quad 28.0 & 23\ 32\ .1\ -15\ .1\,x & \quad 50\ 43 & +\ 59\,x \end{array}\right\}\text{A}$$

Where $x = T -$ Jan. 11.0, T being the unknown time of perihelion passage of the comet's center of gravity. Next were found the following equations, of which the first term is the observed place for these dates, and the term in y is the correction to be applied to give the geocentric coordinates of the comet's center of gravity, assumed to lie in the axis of the tail at an unknown distance, s (expressed in parts of the radius of the earth's orbit), from the point actually taken for observation. The corresponding apparent angular distance will manifestly be, if the tail be assumed to lie in the prolongation of the radius vector,

$$\sigma = s\ \frac{R}{r}\ \frac{\sin x}{\Delta}\ \sin 1'$$

The coefficients of y have been computed from this and the equations in the first part of this article, for $s = 0.00001$. Consequently y is the value of s in units of the fifth decimal place. Thus we have

$$\left.\begin{array}{llll} \text{Jan. } 21.5 & 21^h\ 15^m.9\ +1^m.5\,y & -44^\circ\ 14' & -34'\,y \\ \quad 24.5 & 22\ 11\ .8\ +2\ .8\,y & -47\ 53 & -24\,y \\ \quad 28.0 & 23\ 42\ .0\ +4\ .5\,y & -49\ 28 & -12\,y \end{array}\right\}\text{B}$$

Now, it will be found that no values of x and y can be assumed, by which all the six coordinates in A can be equated with the corresponding ones in B, without discordances which are entirely inadmissible. The presumption is therefore against the similarity of the orbit of this comet with that of 1880 I. But this conclusion is not by any means certain, as it involves assumptions as to the position of the tail, and the constancy of s, which are very problematical.

The orbit above found resembles more those assigned to the comets of 1680 and 1689, than that of the group 1843–80–82. This will more distinctly appear if, instead of comparing the values of ω and Ω, we compute the position of the axes of the parabolas, as indicated by the heliocentric longitude and latitude of the point of perihelion, called l and b in the following table.

Comet	ω	Ω	i	$\log q$	l	b
	° ′	° ′	° ′		° ′	° ′
1843	82 35	361 15	144 19	7.743	280 22	+35 20
1880	77 54	356 17	143 7	7.772	281 17	+35 55
1882	69 36	346 1	142 0	7.885	281 16	+35 15
1689 { Peirce	55 20	344 18	149 45	8.013	292 59	+24 29
1689 { Vogel	180 44	90 25	120 55	8.277	270 2	− 0 38
1680	350 40	272 10	60 40	7.794	267 34	− 8 9
1887	174 49	132 49	57 52	8.363	310 2	+ 4 25

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Another interesting question which I have also thought it worth while to investigate, is whether the observations of the comet of 1668, the character of whose orbit is yet an unsettled problem, will not conform more readily to an orbit like the present one, than to that of 1843. It is simply necessary to say that computation gives a decided negative answer to this question.

As remarked in the beginning, I feel very little confidence that the above orbit represents the actual one. The problem is exceedingly indeterminate. Moderate and entirely warrantable changes in the interpretation of the observations will materially alter the plane and direction of the axis of the parabola.

Cambridge, 1887 *May* 6.

NEW DOUBLE STARS DISCOVERED AT THE LEANDER McCORMICK OBSERVATORY.

Name	α 1890	δ 1890	P.A.	Δ	Mag.	Mag.	Disc.	
	h m s	° ″	°	″				
Oe. Arg. 397	0 40 12	—17 2	192.5	2.47	7	10	M	
DM. +0° 226	1 17 17	+ 1 10	172.2	0.79	9	9	L	∗6.5 p. 20ˢ
Oe. Arg. 1817	2 42 35	—18 47	25.2	2.92	8.7	11	L	1st of 3 9ᴹ st
Schj. 1136	3 39 0	—13 45	0.6	1.11	8.5	10	L	
Anon.	3 47	—13 40	276.±	2.9±	9	10	L	
SDM. —9° 1027	4 51 23	— 9 31	5.±	3.±	9.5	10.5	M	∗8 f. 60ˢ, s 4′
Anon.	6 49 25	—23 4	90.±	1.5±	9	10	L	
SDM. —17° 3651	12 28 24	—17 35	34.0	1.47	7	10	L	
Cord. Z. 2864	13 47 33	—29 44	220.±	3.5±	8	10	M	
Lam. 3427	20 48 4	—11 20	298.4	1.28	8	10	L	
Lam. 3735	21 37 39	—11 38	270.3	1.40	8.5	9.5	L	
Lam. 3849?	22 5 43	—11 34	165.8	0.87	9	9.5	L	1 of 3 st
SDM. —12° 6527	23 31 43	—12 10	301.2	3.15	9	10	M	90ˢ f. β 81

L = F. P. Leavenworth; M = Frank Muller.

1887 *April* 16.

ELEMENTS OF COMET 1887 *d* (*BARNARD.*)

By E. E. BARNARD.

From three of my own positions, on Feb. 16 and 28 and March 12, I have computed the following elements of the comet discovered here on Feb. 16. The positions have been corrected for parallax and aberration by an approximate orbit.

Vanderbilt University, *Nashville*, *Tenn.*, 1887 *April* 28.

Elements.

$$T = 1887 \text{ March } 28.39633 \text{ G. M. T.}$$
$$\left.\begin{aligned}\omega &= 36^\circ\ 28'\ 50''\\ \Omega &= 135^\circ\ 27'\ 17''\\ i &= 139^\circ\ 48'\ 39''\end{aligned}\right\}1887.0$$
$$\log q = 0.00295$$

A CONTINUOUS SPECTRUM FROM HYDROGEN.

By ORRAY T. SHERMAN.

Hydrogen, excited by electric currents of slight intensity, and under pressure not exceeding thirty millimeters, presents a continuous spectrum upon which no bright lines are evident.

Under the dispersions usually employed in astronomical work, it seems comparable to that shown by the nebula in *Andromeda*, or, with less intense illumination, to that of the zodiacal light.

Changes in the relation of the pressure and electrification bring out bright lines upon the continuous background, and at present it would seem as though the continuous spectrum depended upon the relation between these two rather than upon their absolute intensity.

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NEW COMET, 1887 *e*.

A comet was discovered by BARNARD, at Nashville, on the evening of May 12. He gives its place at the time as 58ˢ.9 preceding the star Gen. Catal. 20734, and 11′ 53″ north, which corresponds to

Greenw. M.T.		α	δ
May 12	16ʰ 57ᵐ 22ˢ	15ʰ 10ᵐ 49ˢ.2	—30° 35′ 51″

Motion slow, northeastwardly. Eleventh magnitude.

The following later observations have been communicated:

Place	Local M.T.	α	δ	Observer
	h m s	h m s	° ′ ″	
Cambridge	May 13, 10 59 59	15 12 19.79	—30 6 32.0	Chandler
Albany	13, 11 24 7	15 12 20.42	—30 6 1.3	Boss
Nashville	13, 10 28 43	15 12 21.14	—30 6 6.3	Barnard
Nashville	14, 10 28 57	15 13 17.90	—29 33 59.4	Barnard
Washington	14, 11 30 44	15 13 59.34	—29 33 23.2	Frisby
Albany	15, 12 12 25	15 15 38.41	—28 59 44.7	Boss

TWO HUNDRED SIXTY-SIXTH ASTEROID.

A cable dispatch from Dr. KRUEGER announces the discovery of a planet of the twelfth magnitude by PALISA at Vienna.

Its position was

Greenw. M.T.	α	δ
May 17.5	16ʰ 13ᵐ 12ˢ	—19° 8′

ELEMENTS AND EPHEMERIS OF THE COMET 1887 *e* (*Barnard, May 12*)

BY PROF. LEWIS BOSS.

From the discovery-observation by BARNARD, May 12, observations by CHANDLER, BARNARD and myself, May 14, and an observation at Albany, May 15, I have computed the following elements:

$$\begin{aligned} T &= \text{1887 June 26.682 Greenw. M.T.} \\ \omega &= 27°\ 42'.6 \\ \Omega &= 244\ \ 41.4 \\ i &= 17\ \ \ 2.4 \\ \log q &= 0.10216 \end{aligned} \left.\vphantom{\begin{aligned}\omega\\\Omega\\i\end{aligned}}\right\} \text{Apparent Equinox}$$

Comparison with the middle place gives (C—O):

$$\Delta\lambda \cos\beta = -0'.06$$
$$\Delta\beta = -0.24$$

Dudley Observatory, 1887 *May* 17.

The following ephemeris is computed for Greenwich midnight:

1887	α	δ	log Δ	Light
	h m s	° ′		
May 18.5	15 20 16	—27 17	9.5904	1.3
22.5	15 28 12	24 30	9.5601	1.6
26.5	15 36 52	21 13	9.5324	1.9
30.5	15 46 28	17 29	9.5074	2.2
June 3.5	15 57 4	13 21	9.4869	2.4
7.5	16 8 32	8 54	9.4714	2.6
11.5	16 20 48	— 4 17	9.4618	2.7
15.5	16 33 44	+ 0 21	9.4586	2.8
June 19.5	16 47 4	+ 4 47	9.4614	2.9

The light on May 12 is taken as the unit.

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THE

ASTRONOMICAL JOURNAL.

No. 157.

VOL. VII. BOSTON, 1887 JUNE 6. NO. 13.

OBSERVATIONS OF COMETS

MADE AT THE DUDLEY OBSERVATORY

BY H. V. EGBERT.

Albany M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			***COMET* 1886 *I.* (*Fabry.*)**					
1885 Dec. 2 8 47 10	1	8	—3 33.07	+0 38.5	0 36 15.96	+21 0 24.1	9.074	0.520
2 8 47 10	2	8	—4 27.24	+0 12.5	0 36 16.15	21 0 21.8	9.074	0.520
7 8 47 15	3	20	+1 54.12	—3 45.9	0 24 41.62	20 52 29.4	9.252	0.535
12 8 26 26	4	10	+2 40.69	—1 42.3	0 14 16.95	20 39 37.9	9.292	0.544
25 7 8 40	5	10	—1 11.76	+2 1.3	23 52 41.54	20 41 30.9	9.270	0.540
			***COMET* 1886 *II.* (*Barnard.*)**					
1885 Dec. 7 10 51 25	6	20	+3 22.65	—1 9.8	4 12 9.60	+ 5 4 39.3	n8.376	0.730
12 8 58 0	7	4	+2 49.72	—5 55.2	3 59 56.20	5 34 16.9	n9.546	0.745
25 6 22 14	8	12	+1 20.97	+3 38.3	3 27 20.02	7 14 9.5	n9.464	0.725
1886 Jan. 23 9 9 18	9	12	+7 37.80	+5 30.7	2 27 54.52	12 28 29.2	9.488	0.682
23 9 9 18	10	12	+6 14.48	+1 53.3	2 27 54.53	12 28 35.3	9.488	0.682
26 8 7 50	11	12	—3 22.14	—0 5.2	2 23 41.67	13 5 23.5	9.377	0.659
Feb. 8 8 29 39	12	6	+4 23.19	+6 16.7	2 9 4.49	15 56 58.5	9.564	0.671
			***COMET* 1886 *V.* (*Brooks.*)**					
1886 Apr. 29 12 40 21	13	6	—5 23.59	—0 18.3	0 39 3.80	+61 10 36.0	n9.748	0.866
29 13 4 25	14	10	+1 11.60	—1 1.3	0 39 11.46	61 10 5.1	n9.800	0.842
29 13 4 25	15	10	—0 52.92	—1 41.0	0 39 11.64	61 10 5.1	n9.800	0.842
29 15 43 28	15	8	—0 2.58	—4 31.6	0 40 1.98	61 7 14.5	n9.952	0.540
30 10 16 52	16	10	—0 6.70	+4 27.3	0 46 2.87	60 43 38.3	n8.416	0.934
30 10 30 5	17	14	—2 19.88	+4 41.8	0 46 6.94	60 43 23.3	n8.887	0.933
30 10 30 5	18	14	—3 12.54	+5 22.5	0 46 7.21	60 43 22.1	n8.887	0.933
May 1 11 59 3	19	20	+0 39.44	—1 13.7	0 54 9.74	60 10 3.8	n9.587	0.905
1 11 59 3	20	20	—0 13.74	—0 25.0	0 54 9.77	60 10 3.9	n9.587	0.905
2 12 38 3	21	8	—3 46.23	—6 19.6	1 1 42.53	59 35 55.1	n9.694	0.882
2 12 57 25	22	8	+0 36.89	+3 55.6	1 1 49.86	59 35 22.4	n9.714	0.865
5 11 53 30	23	10	+1 49.40	+0 27.1	1 22 28.78	57 46 8.4	n9.479	0.919
5 11 53 30	24	10	+1 1.76	+1 8.2	1 22 28.27	57 46 10.1	n9.479	0.919
5 12 9 35	25	6	+0 35.62	+5 53.7	1 22 33.50	57 45 34.9	n9.549	0.911
9 14 20 36	26	12	+0 15.56	—6 9.3	1 48 29.84	54 49 2.9	n9.796	0.807
9 14 32 56	27	4	—1 44.31	+0 8.0	1 48 33.93	54 48 43.2	n9.811	0.789
			***COMET* 1886 *III.* (*Brooks.*)**					
1886 May 1 15 38 33	28	8	—4 33.11	+3 23.5	23 8 35.42	+24 38 40.5	n9.658	0.661
1 15 38 33	29	8	—7 38.29	+2 55.5	23 8 35.32	+24 38 45.2	n9.658	0.661

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Albany M.T.	*	No. Comp.	☄ — * Δα	Δδ	☄'s apparent α	δ	log pΔ for α	for δ
COMET 1886 *IV.* (*Brooks.*)								
1886 May 25 12h 12m 58s	30	16	—0m 52s.74	+5′ 3″.9	11h 54m 20s.20	+ 7° 39′ 14″.2	9.610	0.748
28 10 14 54	31	22	—2 6.67	—6 13.2	11 58 50.06	5 49 40.5	9.453	0.735
29 9 59 57	32	20	—1 17.20	+3 4.2	12 0 27.26	5 11 52.4	9.423	0.738
31 10 5 29	33	20	—2 52.14	—5 55.6	12 3 49.80	3 56 12.8	9.446	0.749
June 3 9 57 55	34	12	—0 26.35	—5 58.8	12 9 8.24	2 1 30.4	9.443	0.762
4 9 35 56	35	10	+1 2.74	—5 42.0	12 10 56.61	1 23 10.7	9.393	0.766
COMET 1886 *IX.* (*Barnard.*)								
1886 Oct. 6 17 12 35	36	4	+0 40.42	+6 10.0	10 40 6.80	+ 1 13 37.1	n9.598	0.772
7 17 16 9	37	2	—3 8.44	—1 5.0	10 42 10.42	1 22 14.4	n9.594	0.771
8 16 33 36	38	10	+0 18.79	—1 45.6	10 44 12.83	1 31 0.8	n9.662	0.772
8 17 5 54	39	4	+2 33.36	+2 22.5	10 44 16.32	1 31 8.5	n9.601	0.771
9 16 48 7	40	10	+0 26.79	—1 42.0	10 46 22.29	1 39 43.1	n9.613	0.771
10 17 4 18	40	4	+2 39.15	+7 49.0	10 48 34.65	1 49 14.1	n9.599	0.769
Nov. 1 16 42 43	41	6	—2 27.99	+7 11.0	11 50 49.37	6 45 50.2	n9.600	0.748

Mean Places for 1885.0 of Comparison–Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	0h 39m 45s.43	+3s.60	+20° 59′ 21″.5	+24″.1	Albany Merid. Obs.
2	0 40 39.79	+3.60	+20 59 45.3	+24.0	Albany Merid. Obs.
3	0 22 44.08	+3.42	+20 55 49.9	+25.4	Bonn VI. 20°, 47
4	0 11 32.99	+3.27	+20 40 54.7	+25.5	Bonn VI. 20°, 19
5	23 53 50.34	+2.96	+20 39 2.9	+26.7	Weisse's Bessel 1096
6	4 8 42.84	+4.11	+ 5 5 47.2	+ 1.9	Albany, A.G. Zones
7	3 57 2.35	+4.13	+ 5 40 9.3	+ 2.8	ν Tauri, *Jahrbuch*
8	3 25 55.00	+4.05	+ 7 10 26.0	+ 5.2	Grant 819
Mean Places for 1886.0.					
9	2 20 16.46	+0.26	+12 23 3.6	— 5.1	Grant 543
10	2 21 39.78	+0.27	+12 26 47.2	— 5.2	Bonn VI. 12°, 335
11	2 27 3.56	+0.25	+13 5 34.1	— 5.4	Weisse's Bessel 419
12	2 4 41.35	—0.05	+15 50 46.4	— 4.6	Weisse's Bessel 36
13	0 44 27.93	—0.54	+61 11 3.7	— 9.4	Krueger, Zones 537
14	0 38 0.38	—0.52	+61 11 15.9	— 9.5	Krueger, Zones 401,522
15	0 40 5.07	—0.51	+61 11 55.7	— 9.6	Krueger, Zones 401,542
16	0 46 10.08	—0.51	+60 39 20.6	— 9.6	Krueger, Zones 515,541
17	0 48 27.34	—0.52	+60 38 51.1	— 9.6	Krueger, Zones 530,543
18	0 49 20.28	—0.53	+60 38 9.2	— 9.6	Krueger, Zones 537,544
19	0 53 30.81	—0.51	+60 11 27.2	— 9.7	Krueger, Zones 395,537
20	0 54 24.02	—0.51	+60 10 38.6	— 9.7	Krueger, Zones 530,537
21	1 5 29.28	—0.52	+59 42 24.3	— 9.6	Krueger, Zones 130,131
22	1 1 13.47	—0.50	+59 31 36.5	— 9.7	Krueger, Zones 359,398
23	1 20 39.83	—0.45	+57 45 51.1	— 9.8	Krueger, Zones 325,331
24	1 21 26.97	—0.46	+57 45 11.7	— 9.8	Krueger, Zones 320,331
25	1 21 58.34	—0.46	+57 39 51.0	— 9.8	Krueger, Zones 270,325
26	1 48 14.68	—0.40	+54 55 22.0	— 9.8	Lalande 3454
27	1 50 18.64	—0.40	+54 48 44.9	— 9.7	Oe. Argel 2171.
28	23 13 8.46	+0.07	+24 35 23.4	— 6.4	Weisse's Bessel, 233–4
29	23 16 13.55	+0.06	+24 35 56.1	— 6.4	Weisse's Bessel, 302
30	11 55 11.66	+1.28	+ 7 34 17.0	— 6.7	Grant 3079
31	12 0 55.46	+1.27	+ 5 56 0.4	— 6.7	Weisse's Bessel, 1007
32	12 1 43.14	+1.32	+ 5 8 55.0	— 6.8	Bonn VI. 5°, 2587
33	12 6 40.65	+1.29	+ 4 2 15.2	— 6.8	Albany, A.G. Zones

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*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
34	12 9 33.28	+1.31	+ 2 7 31.4	— 7.2	Albany, A.G. Zones
35	12 9 52.53	+1.34	+ 1 29 00.4	— 7.7	Albany, A.G. Zones
36	10 39 25.54	+0.84	+ 1 7 33.6	— 6.5	Albany, A.G. Zones
37	10 45 18.01	+0.85	+ 1 23 26.0	— 6.6	Albany, A.G. Zones
38	10 43 53.18	+0.86	+ 1 32 53.0	— 6.6	Albany, A.G. Zones
39	10 41 42.10	+0.86	+ 1 28 52.7	— 6.7	Albany, A.G. Zones
40	10 45 54.64	+0.86	+ 1 41 31.8	— 6.7	Albany, A.G. Zones
41	11 53 16.33	+1.03	+ 6 38 48.1	— 8.9	Grant 3074

For star No. 1, Rümker (*Neue Folge*) 276 gives

$0^h\ 39^m\ 44^s.53$, $+20°\ 59'\ 26''.7$ for 1885.0

Dudley Observatory, 1887 *May* 2.

Star No. 26 is in error in Baily's Lalande, and the place was taken from Bonn VII. The observations were made with the ring-micrometer, except those of Comet 1886 IX., after Oct. 6, which were made with the filar-micrometer.

RING-MICROMETER OBSERVATIONS OF COMET 1887 *e* (*Barnard, May 12*)

MADE AT THE VANDERBILT UNIVERSITY OBSERVATORY

BY E. E. BARNARD.

1887 Nashville M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ
d h m s			m s	′ ″	h m s	° ′ ″
May 12 11 10 11	1	9	—0 58.96	+11 52.8		
13 10 28 43	2	10	+1 16.18	— 2 23.2	15 12 21.14	—30 6 6.3
14 10 28 57	3	7	+2 58.76	+10 1.1	15 13 58.19	—29 33 59.4
14 12 2 51	3	5	+3 4.13	+11 52.6	15 14 3.56	—29 32 6.9

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 11 4.5	+2.24	—30 48	—1.6	Equatorial Pointings
2	15 11 2.73	+2.23	—30 3 41.3	—1.8	Yarnall 6275
3	15 10 57.21	+2.22	—29 43 58.6	—1.9	Yarnall 6274

May 12, Comet discovered at $10^h\ 40^m$. May 13, a faint tail preceding, and probably a faint nucleus in elongated condensation.

OBSERVATIONS OF THE COMPANION OF *SIRIUS*

BY PROF. A. HALL.

(Communicated by the Superintendent of the Naval Observatory.)

Date	Sid. Time	*p*	*s*	Wt.	Notes
	h	°	″		
1887.190	8.3	24.0	6.56	3	very faint
1887.226	6.6	22.9	6.67	3	faint
1887.264	7.7	24.6	6.45	3	faint
1887.270	8.0	25.2	6.35	2	faint

MEAN RESULT.

1887.238 $p = 24°.18$ $s = 6''.508$

Washington, 1887 *April* 14.

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ON THE ORBIT OF THE GREAT SOUTHERN COMET 1887 a

By S. C. CHANDLER, Jr.

The computation in the last number of the Journal was completed before I had seen the observations in the *Monthly Notices* for March. It was manifest, upon inspection, that the latter were widely at variance with the estimates of position at Cordoba and Windsor, which I had employed. Thereupon the Cape and Adelaide series were combined into three normal places:

1887 Jan.	22.125	21h 24m 51s.4	−44° 48'.6
	25.000	22 23 13.1	−48 22.7
	27.500	23 19 45.6	−49 40.5

which gave the following orbit:

T	1887 Jan. 11.230 (Greenw.)	
ω	63° 36'.0	True Eq.
Ω	337 42.8	True Eq.
i	137 0.0	True Eq.
log q	7.73892	

Ephemeris.

Greenw. M.T.	α	δ
Jan. 21.0	21h 5m 4s.8	−42° 57'.0
22.0	21 22 33.3	44 37.3
23.0	21 41 31.4	46 7.0
24.0	22 1 50.0	47 23.2
25.0	22 23 18.2	48 24.5
26.0	22 45 34.4	49 6.9
27.0	23 8 19.2	49 34.8
28.0	23 31 4.0	49 43.0
29.0	23 53 26.4	49 34.1
30.0	0 14 58.8	−49 9.0

A comparison with the observations gives the following residuals (O—C):

	Greenw. M.T.	$\Delta\alpha\cos\delta$	$\Delta\delta$
		'	'
Adelaide	Jan. 20.987	+ 1	+23
Adelaide	21.966	−16	+17
Cape	22.313	+17	−41
Cape	23.309	+ 3	0
Cape	24.313	− 2	+ 9
Cape	24.317*	+ 8	−10
Adelaide	24.997	−12	+ 6
Cape	25.323	+ 3	+ 1
Adelaide	26.015	+10	− 7
Adelaide	26.997	+ 7	− 4
Cape	27.319	+ 6	+ 1
Cape	27.344*	+10	−10
Cape	28.346	−16	+20

There is here a tolerably satisfactory alternation of sign, except in the later right ascensions. But if we compare this orbit with the positions employed on page 93 of the Journal, we have the following striking differences:

	Greenw. M.T.	I. $\Delta\alpha\cos\delta$	I. $\Delta\delta$	II. $\Delta\alpha\cos\delta$	II. $\Delta\delta$
		'	'	'	'
Cordoba	Jan. 21.538	+ 2	− 1	+ 18	−29
Cordoba	22.542	− 4	+22	+ 9	− 4
Cordoba	24.540	− 50	+39	− 31	+16
Cordoba	25.531	+ 3	+ 3	+ 24	−18
Cordoba	27.576	+ 70	+61	+ 97	+48
Windsor	27.973	+105	−68	+105	−68
Windsor	29.973	+115	−16	+115	−16

where I. and II. represent, respectively, the comparison with the "observed" and "assumed" positions. The large negative residual in right ascension on the 24th, and the positive residuals on the 27th and 29th, give an entirely different character to the observed geocentric motion, and sufficiently account for the dissimilarity in the elements deduced from this and the Cape and Adelaide series.

In addition to the equatorial pointings made at the Cape, we have an apparently independent set of data of some value, in the sketches upon the *Uranometria Argentina* map. In the case of an object so vaguely defined as this, carefully made naked-eye allineations would probably be quite equal in accuracy to equatorial pointings. The published sketches give the following places (1887) and differences (O—C) from the above orbit:

Greenw. M.T.	α	δ	$\Delta\alpha\cos\delta$	$\Delta\delta$
Jan. 23.324	21h 47m.5	−47° 0'	− 5'	−27'
24.331	22 7.5	47 20	−18	+25
25.341	22 32.7	47 56	+19	+45
27.331	23 18.5	49 41	+25	− 2
28.345	23 42.9	49 21	+40	+21
29.331	23 59.4	−49 35	−13	+ 7

If we unite all the preceding results to form three normal places, combining the observations in the groups January 20.987–23.324, January 24.313–26.015, and January 26.997–29.973, using the "observed" Cordoba positions, and assigning half weight to those taken from the Cape sketches, and quarter weight to the Windsor estimates, we find:

Jan. 22d.200	21h 26m 20s.6	−44° 55'.2
25.000	22 22 50.6	−48 15.0
27.800	23 28 52.2	−49 34.3

An orbit from these normals would doubtless be an improvement upon those above presented, but I have no time to carry the computation further.

TWO HUNDRED SIXTY-SEVENTH ASTEROID

A cable-dispatch, received by the *Science Observer* code, announces a new asteroid of the thirteenth magnitude, discovered by M. Charlois at Nice, May 27.

The position was

Greenw. M.T.	α	δ
May 27.5575	17h 2m 11s.5	−22° 31' 43"

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OBSERVATIONS OF COMET 1887 *e* (*BARNARD*)

MADE WITH THE 9.6 INCH EQUATORIAL AT THE U.S. NAVAL OBSERVATORY, WASHINGTON,

BY PROF. E. FRISBY.

1887 Washington M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
May 14 11 30 44.3 (h m s)	1	15 , 3	+2 59.80	+10 37.6	15 13 59.34	—29 33 23.2	n8.450	0.784
19 12 35 16.2	2	20 , 4	+0 45.23	— 7 4.2	15 22 31.67	—26 35 9.0	9.145	0.857
21 9 42 56.0	3	20 , 4	—0 29.93	+ 3 7.1	15 25 35.52	—25 21 50.0	n9.352	0.834

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 10 57.32	+2.22	—29 43 56.4	—4.4	Gould Gen. Cat. 20721 = *f* Lupi
2	15 21 44.28	+2.16	—26 28 3.4	—1.4	Gould Z. C. XV. 1438
3	15 26 3.30	+2.15	—25 24 56.0	—1.1	½(Gould Z. C. XV. 1742 + *y*, 6384)

NOTE. — The two catalogue positions of * 3 only differ 0s.06 and 0″.2, and the mean of the two positions was taken.

OBSERVATIONS OF *SAPPHO* (80), NEAR OPPOSITION,

MADE AT THE LEANDER McCORMICK OBSERVATORY, UNIVERSITY OF VIRGINIA.

[Communicated by the Director, PROF. ORMOND STONE.]

1887 Greenwich M.T.	*	No. Comp.	(80) — * Δα	(80) — * Δδ	(80)'s apparent α	(80)'s apparent δ	log pΔ for α	log pΔ for δ	Obs'r.
			m s	′ ″	h m s	° ′ ″			
Jan. 10 18 10 55 (h m s)	1	10 , 3	—2 5.88	—1 0.1	7 2 22.59	+ 8 56 53.6	9.185	0.633	L
10 18 6 37	2	11 , 0	—0 46.19		7 2 22.64		9.162		L
15 17 20 22	3	16 , 0	+0 4.93		6 57 8.48		9.010		L
15 17 40 13	3	12	+0 4.08	—5 2.5	6 57 7.63	9 6 8.2	9.152	0.631	L
18 16 9 21	4	7 , 0	+0 12.12				n8.090		M
18 16 21 19	3	7 , 3	—2 51.52	+1 48.7	6 54 12.03	9 12 59.2	8.090	0 626	M
26 18 42 48	5	6 , 1	+1 40.95	+2 9.8	6 47 5.65	9 36 21.2	9.534	0.655	S
27 17 12 8	6	6 , 2	—2 20.36	+1 8.9	6 46 22.64	9 39 24.7	9.299	0.631	S
Feb. 9 16 45 37	7	23 , 7	—0 13.29	—1 58.6	6 39 6.18	+10 26 42.3	9.412	0.629	M

Mean Places for 1887.0 of Comparison-Stars.

Date 1887	*	α	Red. to app. place	δ	Red. to app. place	Authority
		h m s	s	° ′ ″	″	
January 10	1	7 4 27.54	+0.93	+ 8 58 3.8	—10.1	Leipzig
10	2	7 3 7.90	+0.93	+ 9 2 23.0		Leipzig
15	3	6 57 2.60	+0.95	+ 9 11 21.3	—10.6	½(Glasgow + Leipzig)
18	4	6 53 58.9	+0.95	+ 9 9.9		DM. +9° 1375
26	5	6 45 23.74	+0.96	+ 9 34 22.5	—11.1	½(Glasgow + Leipzig)
27	6	6 48 42.04	+0.96	+ 9 38 27.0	—11.2	Leipzig
February 9	7	6 39 18.51	+0.96	+10 28 52.3	—11.4	Leipzig

S = Ormond Stone; L = F. P. Leavenworth; M = Frank Muller.

The second set of observations on January 15 was made by observing several sets of transits over the micrometer-wires, placed at an angle of 45°, with the declination circle. The position-circle was then rotated through 90°, and an equal number of transits observed with the wires set at an angle of 45°, on the opposite side of the declination-circle. The remaining observations are comparisons of right-ascension and declination made in the usual way. All the observations were corrected for refraction but not for parallax. Mr. LEAVENWORTH estimated the magnitude of *Sappho* on January 10 as 11M; on January 15 as 10M. The positions of comparison-stars observed at Leipzig were kindly furnished by DR. BRUNS.

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OBSERVATIONS OF THE COMET 1886 IV

MADE AT THE PRINCETON OBSERVATORY, NEW JERSEY, WITH THE 23-INCH EQUATORIAL AND DIAGONAL SQUARE-BOX MICROMETER.

[Communicated by the Director, PROF. C. A. YOUNG.]

1886 Greenwich M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs'r
d h m s			m s	′ ″	h m s	° ′ ″			
May 25 14 5 38	1	7	+0 30.10	+12 25.7	11 54 8.84	7 44 4.3	n9.227	n0.682	Y
25 14 33 23	2	10	−1 2.54	+ 9 6.6	11 54 10.36	7 43 17.1	n9.303	n0.684	Y
26 15 6 14	3	5	+0 38.94	− 9 50.6	11 55 42.07	7 5 2.2	n9.445	n0.699	Y
26 15 6 14	4	5	+0 3.21	− 3 15.2	11 55 42.12	7 5 4.0	n9.445	n0.699	Y
28 14 13 7	5	12	−1 15.93	− 8 7.8	11 58 46.12	5 51 18.7	n9.289	n0.703	Y
June 5 14 54 34	6	5	+1 17.45	+ 7 9.7	12 12 52.73	0 44 24.6	n9.464	n0.751	Y
5 14 54 34	7	5	+0 57.77	+ 4 36.6	12 12 52.60	0 44 17.8	n9.464	n0.751	Y
5 15 10 26	6	5	+1 15.73	+ 7 27.4	12 12 51.01	0 44 42.3	n9.497	n0.751	McN
5 15 10 26	7	5	+0 55.95	+ 4 52.8	12 12 50.78	0 44 34.0	n9.497	n0.751	McN

Mean Places for 1886.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	11 53 37.47	+1.27	7 31 45.3	−6.7	Weisse's Bessel XI, 891
2	11 55 11.64	+1.26	7 34 17.2	−6.7	Glasgow 3079
3	11 55 1.87	+1.26	7 14 59.5	−6.7	Brit. Naut. Alm., π *Virginis*
4	11 55 37.64	+1.27	7 8 25.9	−6.7	Glasgow 3081
5	12 0 0.80	+1.26	5 59 33.2	−6.7	Glasgow 3099
6	12 11 33.96	+1.32	0 37 22.1	−7.2	Schjellerup 4433
7	12 11 53.51	+1.32	0 39 48.4	−7.2	Weisse's Bessel XII, 148

The observations marked Y. are by Prof. YOUNG; those marked McN. are by Mr. MALCOLM MCNEILL.

Observations corrected for proper-motion of comet, refraction and orientation of square.

May 26. Observations interrupted by clouds.

May 28. Comet about 1½′ in diameter, very diffuse and faint, no good center, observations difficult and not very good, sky not very dark.

June 5. Comet very faint and diffuse, 4′± in diameter. Observations extremely uncertain.

In all the observations, and especially in those of June 5, the right-ascensions, as determined by disappearance behind the bar, are less than those determined by the reappearances, the average difference being about $1^s.5$. There [illegible] evidence of a large personal equation between Y. and M[illegible] the observations of June 5.

ON THE VARIABLE STAR [illegible] SAGITT[illegible]

$19^h\ 49^m\ 25^s$, $+16°\ 15'.4$ [illegible])

BY EDWIN F. SAW[illegible]

From my observations, 43 in number, of [illegible] extending from September 18 to December 9, 188[illegible] [illegible]llowing times of maxima and minima have been deduc[illegible]

OBSERVED MAXIMA.

E	Camb. M.T.	Wt.	O–C
	d		d
426	1886 Sept. 23.27	3	−0.32
427	Oct. 1.40	3	−0.58
428	10.30	1	−0.07
429	18.81	2	+0.07
431	Nov. 4.38	4	−0.13
432	12.96	1	+0.07
433	20.43	2	−0.84
434	29.15	1	−0.50
435	Dec. 7.91	1	−0.13

[illegible]ments [illegible] a cor- [illegible] prob-

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able error of $\pm 0^d.07$. The correction of the assumed period would appear to be $-0^m.96$, which substantially agrees with that found by Mr. REED in No. 155 of this *Journal.*

The light-curve appears very flat at minimum, much more so than is usually the case, consequently this phase cannot be determined with sharpness from the observations. The increase of light is rapid, and there is a notable inflection in the light-curve after maximum, which has also been pointed out by Mr. CHANDLER. The minimum apparently occurs about $2^d.8$ before maximum.

From the observations the following first approximation to the light-curve is found:

BEFORE MAXIMUM.

$-3^d.0$	$L = 5.5$	$-1^d.0$	$L = 9.9$
-2.5	$L = 5.4$	-0.5	$L = 15.2$
-2.0	$L = 5.5$	-0.0	$L = 16.0$
-1.5	$L = 6.7$		

AFTER MAXIMUM.

$0^d.0$	$L = 16.0$	$+3^d.5$	$L = 7.5$
$+0.5$	$L = 15.8$	$+4.0$	$L = 6.4$
$+1.0$	$L = 15.1$	$+4.5$	$L = 6.0$
$+1.5$	$L = 14.0$	$+5.0$	$L = 5.7$
$+2.0$	$L = 13.0$	$+5.5$	$L = 5.5$
$+2.5$	$L = 12.1$	$+6.0$	$L = 5.4$
$+3.0$	$L = 10.9$		

Cambridgeport, 1887 *May* 13.

FILAR-MICROMETER OBSERVATIONS OF COMET 1887 *e*

MADE AT THE DUDLEY OBSERVATORY

BY LEWIS BOSS.

1887 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	$\Delta\delta$	☄'s apparent α	δ	log $p\Delta$ for α	for δ
May 13 11h 24m 5s	1	30 , 10	+1m 15s.11	—2′ 21″.5	15h 12m 20s.24	—30° 6′ 1″.9	n8.591	0.925
15 12 12 25	2	7	—0 17.04	—3 34.2	15 15 38.41	—28 59 44.7	7.653	0.922
18 12 30 4	3	15 , 5	—0 38.95	+0 45.0	15 20 46.04	—27 13 12.0	9.069	0.939
23 12 20 45	4	18 , 6	—0 52.20	+6 15.4	15 29 46.51	—23 55 49.4	9.068	0.904
23 13 13 37	5	9 , 3	—5 27.51	+1 50.5	15 29 50.32	—23 54 17.2	9.341	0.892

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	15h 11m 2s.90	+2s.23	—30° 3′ 38″.6	—1″.8	Cordoba Zones and Yarnall
2	15 15 53.24	+2.21	—28 56 8.8	—1.7	Yarnall, Cape and Argentine G.C.
3	15 21 22.82	+2.17	—27 13 55.5	—1.5	Cordoba Zones
4	15 30 36.56	+2.15	—24 2 3.9	—0.9	Cordoba Zones and Oeltzen's Argel. (½ Wt.)
5	15 35 15.68	+2.15	—23 56 7.1	—0.6	See note at end of Remarks

REMARKS.

The observations have been corrected for refraction. May 13, the comet is extremely condensed, and has a star-like nucleus estimated to be of the magnitude 11.5. May 15, the comet is scarcely visible through the dense smoke which prevails near the horizon. May 18, extremely difficult through light clouds and smoke. May 23, the first comparison with O.A. 14700 is somewhat weak, owing to the presence of clouds rendering the comet very faint. At 13h A.M.T. the sky cleared and the comet became an easy object in the second set of comparisons. Nucleus star-like. Magnitude, 11.0.

The second comparison-star, used on May 23 (Ll. 28551 = OA 14773–4–5), appears to have a decided proper-motion in right-ascension. I have reduced anew, by the help of Von Asten's tables, Lalande's observation of June 6, 1799, and to the declinations of Lalande and Argelander I have added $-1''.6$ for systematic correction to the system of the American Ephemeris. The resulting position for 1887.0 is

$$\alpha = 15^h\,35^m\,15^s.68 - 0^s.009\,t; \quad \text{and } \delta = -23^\circ\,56'\,7''.1 - 0''.05\,t.$$

In the table, columns I and III give the seconds respectively of α and δ for 1887.0 as they would result on the assumption of no proper-motion; and columns II and IV, the same with the application of the proper-motions $-0^s.009$ and $-0''.05$ in α and δ respectively.

	Epoch	Obs.	Wt.	I (s)	II (s)	III (″)	IV (″)
Lalande	1799.4	1	.1	16.48	15.66	1.6	6.0
Wash. Mur. Z.	1848.5	1	.05	16.17	15.81	5.7	7.6
Wash. Tr. Z.	1849.3	1	.05	15.90	15.55	4.9	6.8
Oe. Arg. (S)	(1850)	3	.3	16.04	15.70	6.8	8.1
Cord. Zones	(1874)	3	.5	15.83	15.71	6.7	7.3
Arg. Gen. Cat.	1879.6	2	1.0	15.74	15.67	6.5	6.9

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OBSERVATIONS OF THE COMET 1886 IV

MADE AT THE PRINCETON OBSERVATORY, NEW JERSEY, WITH THE 23-INCH EQUATORIAL AND DIAGONAL SQUARE-BOX MICROMETER.

[Communicated by the Director, PROF. C. A. YOUNG.]

1886 Greenwich M.T.	*	No. Comp.	☄—* $\Delta\alpha$	☄—* $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs'r
d h m s			m s	′ ″	h m s	° ′ ″			
May 25 14 5 38	1	7	+0 30.10	+12 25.7	11 54 8.84	7 44 4.3	n9.227	n0.682	Y
25 14 33 23	2	10	—1 2.54	+ 9 6.6	11 54 10.36	7 43 17.1	n9.303	n0.684	Y
26 15 6 14	3	5	+0 38.94	— 9 50.6	11 55 42.07	7 5 2.2	n9.445	n0.699	Y
26 15 6 14	4	5	+0 3.21	— 3 15.2	11 55 42.12	7 5 4.0	n9.445	n0.699	Y
28 14 13 7	5	12	—1 15.93	— 8 7.8	11 58 46.12	5 51 18.7	n9.289	n0.703	Y
June 5 14 54 34	6	5	+1 17.45	+ 7 9.7	12 12 52.73	0 44 24.6	n9.464	n0.751	Y
5 14 54 34	7	5	+0 57.77	+ 4 36.6	12 12 52.60	0 44 17.8	n9.464	n0.751	Y
5 15 10 26	6	5	+1 15.73	+ 7 27.4	12 12 51.01	0 44 42.3	n9.497	n0.751	McN
5 15 10 26	7	5	+0 55.95	+ 4 52.8	12 12 50.78	0 44 34.0	n9.497	n0.751	McN

Mean Places for 1886.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	11 53 37.47	+1.27	7 31 45.3	—6.7	Weisse's Bessel XI, 891
2	11 55 11.64	+1.26	7 34 17.2	—6.7	Glasgow 3079
3	11 55 1.87	+1.26	7 14 59.5	—6.7	Brit. Naut. Alm., π *Virginis*
4	11 55 37.64	+1.27	7 8 25.9	—6.7	Glasgow 3081
5	12 0 0.80	+1.26	5 59 33.2	—6.7	Glasgow 3099
6	12 11 33.96	+1.32	0 37 22.1	—7.2	Schjellerup 4433
7	12 11 53.51	+1.32	0 39 48.4	—7.2	Weisse's Bessel XII, 148

The observations marked Y. are by Prof. YOUNG; those marked McN. are by Mr. MALCOLM MCNEILL.

Observations corrected for proper-motion of comet, refraction and orientation of square.

May 26. Observations interrupted by clouds.

May 28. Comet about 1½′ in diameter, very diffuse and faint, no good center, observations difficult and not very good, sky not very dark.

June 5. Comet very faint and diffuse, 4′± in diameter. Observations extremely uncertain.

In all the observations, and especially in those of June 5, the right-ascensions, as determined by disappearance behind the bar, are less than those determined by the reappearances, the average difference being about 1s.5. There is also evidence of a large personal equation between Y. and McN., from the observations of June 5.

ON THE VARIABLE STAR *F.10 SAGITTAE*

$19^h\ 49^m\ 25^s$, $+16°\ 15'.4$ (1855.0)

BY EDWIN F. SAWYER.

From my observations, 43 in number, of this star, extending from September 18 to December 9, 1886, the following times of maxima and minima have been deduced:

OBSERVED MAXIMA.

E	Camb. M.T.	Wt.	O—C
	d		d
426	1886 Sept. 23.27	3	—0.32
427	Oct. 1.40	3	—0.58
428	10.30	1	—0.07
429	18.81	2	+0.07
431	Nov. 4.38	4	—0.13
432	12.96	1	+0.07
433	20.43	2	—0.84
434	29.15	1	—0.50
435	Dec. 7.91	1	—0.13

OBSERVED MINIMA.

E	Camb. M.T.	Wt.	O—C
	d		d
426	1886 Sept. 20.14	3	—0.45
427	29.15	2	+0.17
428	Oct. 7.06	3	—0.31
429	15.79	2	+0.04
430	23.76	5	—0.37
431	Nov. 1.76	2	+0.26
432	9.59	2	—0.31
433	17.99	3	—0.29
434	26.55	3	—0.11

By a comparison of these determinations with the elements given by CHANDLER in the *Astr. Nachr.* 2749, I find a correction of —0d.29 for the epoch of maximum, with a prob-

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able error of $\pm 0^d.07$. The correction of the assumed period would appear to be $-0^m.96$, which substantially agrees with that found by Mr. REED in No. 155 of this *Journal*.

The light-curve appears very flat at minimum, much more so than is usually the case, consequently this phase cannot be determined with sharpness from the observations. The increase of light is rapid, and there is a notable inflection in the light-curve after maximum, which has also been pointed out by Mr. CHANDLER. The minimum apparently occurs about $2^d.8$ before maximum.

From the observations the following first approximation to the light-curve is found:

BEFORE MAXIMUM.

$-3^d.0$	$L = 5.5$	$-1^d.0$	$L = 9.9$
-2.5	$L = 5.4$	-0.5	$L = 15.2$
-2.0	$L = 5.5$	-0.0	$L = 16.0$
-1.5	$L = 6.7$		

AFTER MAXIMUM.

$0^d.0$	$L = 16.0$	$+3^d.5$	$L = 7.5$
$+0.5$	$L = 15.8$	$+4.0$	$L = 6.4$
$+1.0$	$L = 15.1$	$+4.5$	$L = 6.0$
$+1.5$	$L = 14.0$	$+5.0$	$L = 5.7$
$+2.0$	$L = 13.0$	$+5.5$	$L = 5.5$
$+2.5$	$L = 12.1$	$+6.0$	$L = 5.4$
$+3.0$	$L = 10.9$		

Cambridgeport, 1887 *May* 13.

FILAR-MICROMETER OBSERVATIONS OF COMET 1887 *e*

MADE AT THE DUDLEY OBSERVATORY

BY LEWIS BOSS.

1887 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
May 13 11h 24m 5s	1	30 , 10	+1m 15s.11	−2′ 21″.5	15h 12m 20s.24	−30° 6′ 1″.9	n8.591	0.925
15 12 12 25	2	7	−0 17.04	−3 34.2	15 15 38.41	−28 59 44.7	7.653	0.922
18 12 30 4	3	15 , 5	−0 38.95	+0 45.0	15 20 46.04	−27 13 12.0	9.069	0.939
23 12 20 45	4	18 , 6	−0 52.20	+6 15.4	15 29 46.51	−23 55 49.4	9.068	0.904
23 13 13 37	5	9 , 3	−5 27.51	+1 50.5	15 29 50.32	−23 54 17.2	9.341	0.892

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	15h 11m 2s.90	+2s.23	−30° 3′ 38″.6	−1″.8	Cordoba Zones and Yarnall
2	15 15 53.24	+2.21	−28 56 8.8	−1.7	Yarnall, Cape and Argentine G.C.
3	15 21 22.82	+2.17	−27 13 55.5	−1.5	Cordoba Zones
4	15 30 36.56	+2.15	−24 2 3.9	−0.9	Cordoba Zones and Oeltzen's Argel. (½ Wt.)
5	15 35 15.68	+2.15	−23 56 7.1	−0.6	See note at end of Remarks

REMARKS.

The observations have been corrected for refraction. May 13, the comet is extremely condensed, and has a star-like nucleus estimated to be of the magnitude 11.5. May 15, the comet is scarcely visible through the dense smoke which prevails near the horizon. May 18, extremely difficult through light clouds and smoke. May 23, the first comparison with O.A. 14700 is somewhat weak, owing to the presence of clouds rendering the comet very faint. At 13h A.M.T. the sky cleared and the comet became an easy object in the second set of comparisons. Nucleus star-like. Magnitude, 11.0.

The second comparison-star, used on May 23 (Ll. 28551 = OA 14773–4–5), appears to have a decided proper-motion in right-ascension. I have reduced anew, by the help of Von Asten's tables, Lalande's observation of June 6, 1799, and to the declinations of Lalande and Argelander I have added $-1''.6$ for systematic correction to the system of the American Ephemeris. The resulting position for 1887.0 is

$$\alpha = 15^h\,35^m\,15^s.68 - 0^s.009\,t; \quad \text{and } \delta = -23^\circ\,56'\,7''.1 - 0''.05\,t.$$

In the table, columns I and III give the seconds respectively of α and δ for 1887.0 as they would result on the assumption of no proper-motion; and columns II and IV, the same with the application of the proper-motions $-0^s.009$ and $-0''.05$ in α and δ respectively.

	Epoch	Obs.	Wt.	I	II	III	IV
				s	s	″	″
Lalande	1799.4	1	.1	16.48	15.66	1.6	6.0
Wash. Mur. Z.	1848.5	1	.05	16.17	15.81	5.7	7.6
Wash. Tr. Z.	1849.3	1	.05	15.90	15.55	4.9	6.8
Oe. Arg. (S)	(1850)	3	.3	16.04	15.70	6.3	8.1
Cord. Zones	(1874)	3	.5	15.83	15.71	6.7	7.3
Arg. Gen. Cat.	1879.6	2	1.0	15.74	15.67	6.5	6.9

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ELEMENTS AND EPHEMERIS OF COMET 1887 *e* (*Barnard, May 12*)

By S. C. CHANDLER, Jr.

The following orbit has been computed from seventeen observations by Boss, Frisby, Wendell, Barnard, and myself. After correcting for parallax and aberration, these were combined into four normals (mean equinox 1887.0), as follows:

	Obs.	Greenw. M.T.	α	δ
			h m s	° ′ ″
May 12-15	8	May 14.17553	15 13 8.03	—29 49 55.5
18-21	4	19.21495	21 36.88	26 54 37.0
23-25	3	24.36918	30 59.48	23 28 10.9
30	2	30.62988	43 18.20	18 48 35.2

These give the following elements:

$$\begin{aligned} T &= \text{June } 16.73745 \text{ Greenw. M.T.} \\ \omega &= 15^\circ\ 11'\ 53''.6 \\ \Omega &= 245\ \ 13\ \ \ 1\ .9 \\ i &= 17\ \ 35\ \ 18\ .4 \\ \log q &= 0.144408 \end{aligned} \left.\vphantom{\begin{aligned} a\\ b\\ c\end{aligned}}\right\} \text{Eq. } 1887.0$$

The deviations of the two middle places (C—O) are

	May 19	May 24
$\Delta\lambda \cos\beta$	—1″.8	—2″.0
$\Delta\beta$	+0 .6	—2 .3

Ephemeris for Greenwich Midnight.

1887	App. α	Hourly Motion	App. δ	Hourly Motion	log *r*	log Δ	Light
	h m s	s	° ′ ″	″			
June 3.5	15 51 22.52	+5.308	—15 46 9.2	+118.95	0.148514	9.604564	1.62
5.5	55 39.19	5.387	14 10 46.9	119.29			
7.5	15 59 59.48	5.456	12 35 30.5	118.75	0.146419	9.602066	1.66
9.5	16 4 22.86	5.516	10 0 59.6	117.40			
11.5	8 48.86	5.564	9 27 52.3	115.27	0.145057	9.603651	1.66
13.5	13 16.92	5.603	7 56 45.3	112.40			
15.5	17 46.56	5.630	6 28 12.8	108.84	0.144444	9.609160	1.62
17.5	22 17.24	5.647	5 2 45.6	104.70			
19.5	26 48.58	5.657	3 40 50.1	100.03	0.144588	9.618289	1.56
21.5	31 20.21	5.659	2 22 49.0	94.95			
23.5	35 51.78	5.654	— 1 8 59.6	89.56	0.145488	9.630610	1.47
25.5	40 22.96	5.644	+ 0 0 25.0	83.94			
27.5	44 53.46	5.626	1 5 16.6	78.19	0.147133	9.645624	1.36
29.5	49 22.90	5.600	2 5 30.6	72.39			
July 1.5	53 50.99	5.569	3 1 6.6	66.60	0.149502	9.662825	1.24
3.5	16 58 17.41	5.531	3 52 6.3	60.90			
5.5	17 2 41.91	5.489	4 38 34.5	55.30	0.152568	9.681743	1.12
7.5	7 4.32	5.444	5 20 36.6	49.92			
9.5	17 11 24.45	+5.396	+ 5 58 17.8	+ 44.80	0.156298	9.701997	1.01

Cambridge, 1887 *June* 1.

CORRIGENDA.

No. 156, p. 89. Lines 1 and 2 from bottom, for ⅛ put ⅓.

p. 96. Line 11, Nashville right-ascension, for 17ˢ.90 put 57ˢ.90.

CONTENTS.

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THE

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ON CERTAIN INEQUALITIES IN THE MOON'S MOTION ARISING FROM THE ACTION OF THE PLANETS.

By JOHN N. STOCKWELL.

Introduction.

1. In the year 1876 Prof. Newcomb published a detailed discussion of the comparison of Hansen's *Lunar Tables*, with observations, for the purpose of making the lunar ephemeris as serviceable as possible in the determination of the longitudes of the stations from which the Transit of Venus was observed in the year 1874. An incidental result of the discussion was the discovery of an equation in the moon's longitude having a period somewhere between fifteen and twenty years, and for which no theoretical cause could be assigned.

2. The thoroughness with which the theory of the sun's action on the moon's motion had been developed by different investigators, precluded the possibility of such an inequality being due to solar attraction; and the same might be said in regard to the effect of the earth's oblateness, notwithstanding its period was so nearly the same as that of the moon's node, on which an important lunar inequality depends. The question therefore seemed to be narrowed to the discussion of the existence of a planetary inequality having the same magnitude and period as the empirical equation which had been deduced from the observations.

3. About two years after the discovery of the inequality referred to, Mr. E. Neison discovered two inequalities in the moon's motion arising from the attraction of *Jupiter*, and having periods of 27.43 days, and 17.43 years, respectively. They correspond in form to the evection and its associated inequality of long period which depend on the sun's action. The period of the latter inequality agrees well with that assigned by observation, but its magnitude was considerably larger. No attempt was made to verify the accuracy of Mr. Neison's calculations until about two years ago, when Mr. G. W. Hill, of the *Nautical Almanac Office*, entered into an exhaustive discussion of the theory of these inequalities, and obtained for the coefficient of the long-period inequality only about *one-tenth* of the value assigned by Mr. Neison. Mr. Neison, however, noticed only the lowest order of terms depending on the eccentricity of the moon's orbit, which entered into the formation of the coefficient, while Mr. Hill, with his characteristic thoroughness, has had the leisure, patience and perseverance to extend his approximations so as to include terms two orders higher in his coefficients. Mr. Hill has employed Delaunay's method of computing the perturbations, and I have thought that it might be of interest to astronomers to give the application of other methods of investigation to the same problem. The terms of higher order were found by Mr. Hill to be of very little importance, and I have, in this investigation, only noticed the terms of lowest order which enter into the coefficients. I have, in the first place, given the general development of the disturbing function, and have afterwards considered the particular inequalities discussed by Mr. Hill, together with such other inequalities as may contribute to the formation of their coefficients.

4. The result of my investigation may be stated in few words. I find that the coefficient of the long-period term given by Mr. Hill is about *fourteen* times, and that of Mr. Neison *one hundred and fifty* times too large; and that the coefficient of the evection-term, which is given by both of these distinguished calculators, is totally erroneous; so much so indeed that it does not even give the *direction* in which the perturbation takes place. It is therefore evident that the action of *Jupiter* on the moon's motion is inadequate to explain the empirical equation discovered by Prof. Newcomb.

Perturbations of the Moon's Motion Arising from the Action of the Planets.

5. If we denote the rectangular coordinates of a planet, referred to the center of the earth as the origin, by X, Y, Z, and if x, y, z denote the coordinates of the moon referred to the same origin, the disturbing function R will be given by the equation,

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$$R = \frac{m''}{f^3}\{Xx + Yy + Zz\} - m''\{(X-x)^2 + (Y-y)^2 + (Z-z)^2\}^{-\frac{1}{2}} \tag{1}$$

in which m'' denotes the planet's mass, and f denotes the planet's distance from the earth.

If the heliocentric coordinates of the earth and planet are denoted by x', y', z'; x'', y'', z''; respectively, we shall have

$$X = x'' - x', \qquad Y = y'' - y', \qquad Z = z'' - z', \tag{2}$$

and the functions R and f will become

$$R = \frac{m''}{f^3}\{(xx'' + yy'' + zz'') - (xx' + yy' + zz')\} - m''\{(x'' - x' - x)^2 + (y'' - y' - y)^2 + (z'' - z' - z)^2\}^{-\frac{1}{2}} \tag{3}$$

$$f = \{(x'' - x')^2 + (y'' - y')^2 + (z'' - z')^2\}^{\frac{1}{2}} \tag{4}$$

Now we have

$$\begin{aligned} &\{(x'' - x' - x)^2 + (y'' - y' - y)^2 + (z'' - z' - z)^2\}^{-\frac{1}{2}} = \\ &= \frac{1}{f} + \frac{1}{f^3}\{(xx'' + yy'' + zz'') - (xx' + yy' + zz') - \tfrac{1}{2}r^2\} + \tfrac{3}{2}\frac{1}{f^5}\{(xx'' + yy'' + zz'') - (xx' + yy' + zz') - \tfrac{1}{2}r^2\}^2 \end{aligned} \tag{5}$$

neglecting the terms depending on the *seventh* and higher powers of f.

If we substitute this in equation (3), it will become

$$R = -\frac{m''}{f} + \tfrac{1}{2}\frac{m''r^2}{f^3} - \tfrac{3}{2}\frac{m''}{f^5}\{(xx'' + yy'' + zz'') - (xx' + yy' + zz') - \tfrac{1}{2}r^2\}^2 \tag{6}$$

We shall now transform this equation to polar coordinates, and shall take the ecliptic for the fundamental plane, in which case we evidently have $z' = 0$. Then we shall have

$$\begin{array}{lll} x = r\cos\theta\cos v & x' = r'\cos v' & x'' = r''\cos\theta''\cos v'' \\ y = r\cos\theta\sin v & y' = r'\sin v' & y'' = r''\cos\theta''\sin v'' \\ z = r\sin\theta & z' = 0 & z'' = r''\sin\theta'' \end{array} \tag{7}$$

Then we obtain

$$\begin{aligned} xx'' + yy'' + zz'' &= rr''\{\cos\theta\cos\theta''\cos(v - v'') + \sin\theta\sin\theta''\} \\ xx' + yy' + zz' &= rr'\cos\theta\cos(v - v') \\ f &= \{r''^2 + r'^2 - 2r'r''\cos(v' - v'')\}^{\frac{1}{2}} \end{aligned} \tag{8}$$

The value of R therefore becomes

$$R = -\frac{m''}{f} + \frac{\frac{1}{2}m''r^2}{f^3} - \tfrac{3}{2}\frac{m''}{f^5}\{rr''[\cos\theta\cos\theta''\cos(v - v'') + \sin\theta\sin\theta''] - rr'\cos\theta\cos(v - v') - \tfrac{1}{2}r^2\}^2 \tag{9}$$

This equation may easily be reduced to the following:

$$\begin{aligned} R = &-\frac{m''}{f} - \frac{m''r^2}{4f^3} + \frac{3m''r^2\sin^2\theta}{4f^3} \\ &- \tfrac{3}{2}\frac{m''}{f^5}\Big\{\tfrac{1}{4}r^4 - \tfrac{1}{2}r^2r''^2\cos^2\theta\sin^2\theta'' - r^3r''\sin\theta\sin\theta'' + \tfrac{1}{2}r^2r''^2\cos^2\theta\cos^2\theta''\cos 2(v - v'') \\ &\quad + r^2\cos\theta\{2r''^2\sin\theta\sin\theta''\cos\theta'' - rr''\cos\theta''\}\cos(v - v'') + \tfrac{1}{2}r^2r'^2\cos^2\theta\cos 2(v - v') \\ &\quad + r^2\{rr' - 2r'r''\sin\theta\sin\theta''\}\cos\theta\cos(v - v') - r^2r'r''\cos^2\theta\cos\theta''\cos(2v - v' - v'')\Big\} \end{aligned} \tag{10}$$

6. Having given the analytical expression for the disturbing function, we shall now apply it to the determination of some of the principal inequalities arising from the action of the planet *Jupiter* on the motion of the moon.

The arguments of the two inequalities which we have mentioned in the Introduction, arise from the development of the term of R which depends on the angle $2(v - v'')$. We may secure the desired degree of accuracy in the calculations if we neglect the inclinations of the orbits of the moon and *Jupiter*, and we may also suppose the orbit of *Jupiter* to be circular. In our further investigation we may therefore suppose that

$$R = -\tfrac{3}{4}\frac{m''}{f^5}r^2a''^2\cos 2(v - v'') \tag{11}$$

in which a'' denotes the mean distance of *Jupiter* from the sun. Equation (11) gives

$$\begin{aligned} \left(\frac{dR}{dr}\right) &= -\tfrac{3}{2}\frac{m''a''^2}{f^5}r\cos 2(v - v'') \\ \left(\frac{dR}{dv}\right) &= \tfrac{3}{2}\frac{m''a''^2}{f^5}r^2\sin 2(v - v'') \end{aligned} \tag{12}$$

In order to develop these equations, we have, with sufficient accuracy for our purpose,

$$\begin{aligned} r &= a\{1 + \tfrac{1}{2}e^2 - e\cos(nt - \omega) - \tfrac{1}{2}e^2\cos 2(nt - \omega)\} \\ v &= nt + 2e\sin(nt - \omega) + \tfrac{5}{4}e^2\sin 2(nt - \omega) \\ v'' &= n''t \qquad v' = n't \qquad r' = a' \qquad r'' = a'' \end{aligned} \tag{13}$$

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Whence we get

$$\cos 2(v-v'') = \left.\begin{matrix}\{1-4e^2\}\cos 2(nt-n''t) + 2e\cos(3nt-2n''t-\omega) - 2e\cos(nt-2n''t+\omega) \\ + \tfrac{13}{4}e^2\cos(4nt-2n''t-2\omega) + \tfrac{3}{4}e^2\cos 2(n''t-\omega)\end{matrix}\right\} \tag{14}$$

$$\sin 2(v-v'') = \left.\begin{matrix}\{1-4e^2\}\sin 2(nt-n''t) + 2e\sin(3nt-2n''t-\omega) - 2e\sin(nt-2n''t+\omega) \\ + \tfrac{13}{4}e^2\sin(4nt-2n''t-2\omega) - \tfrac{3}{4}e^2\sin 2(n''t-\omega)\end{matrix}\right\} \tag{15}$$

The value of f also becomes

(16) $$f = a''\{1+\alpha^2-2\alpha\cos(n't-n''t)\}^{\frac{1}{2}}$$

in which

(17) $$\alpha = a' \div a''$$

Equation (16) gives

(18) $$f^{-5} = \frac{1}{a''^5}\{1+\alpha^2-2\alpha\cos(n't-n''t)\}^{-\frac{5}{2}}$$

and the development of this equation gives for the part which is independent of the cosines

$$f^{-5} = \frac{1}{a''^5}(1.25953) \tag{19}$$

If we now make the necessary substitutions in equations (12), and put

$$\overline{m}^2 = \frac{m''a^3}{a''^3} \tag{20}$$

they will become

$$\left(\frac{dR}{dr}\right) = \frac{\overline{m}^2}{2a^2}\left\{\begin{matrix}-\{1-\tfrac{7}{2}e^2\}(3.77859)\cos 2(nt-n''t) - e(5.66789)\cos(3nt-2n''t-\omega) \\ + e(9.44648)\cos(nt-2n''t+\omega) - e^2(7.55718)\cos(4nt-2n''t-2\omega) - e^2(5.66789)\cos 2(n''t-\omega)\end{matrix}\right\} \tag{21}$$

$$\left(\frac{dR}{dv}\right) = \frac{\overline{m}^2}{2a^2}\left\{\begin{matrix}\{1-\tfrac{5}{2}e^2\}(3.77859)\sin 2(nt-n''t) + e(3.77859)\sin(3nt-2n''t-\omega) \\ + e(11.33577)\sin(nt-2n''t+\omega) + e^2(3.77859)\sin(4nt-2n''t-2\omega) - e^2(9.44648)\sin 2(n''t-\omega)\end{matrix}\right\} \tag{22}$$

7. Having found the expressions for the forces, we must now substitute them in the following equations:

$$\frac{d\delta_0 r}{dt} = an\left\{e\sin(nt-\omega) + e^2\sin 2(nt-\omega)\right\}\int\left(\frac{dR}{dv}\right)dt \tag{23}$$

$$\frac{d\delta_1 r}{dt} = \frac{1}{\sqrt{a\mu}}c_1\cos\beta\int\left\{c_2\cos\beta\left(\frac{dR}{dr}\right) + c_3\sin\beta\left(\frac{dR}{dv}\right)\right\} - \frac{1}{\sqrt{a\mu}}c_1\sin\beta\int\left\{c_2\sin\beta\left(\frac{dR}{dr}\right) + c_3\cos\beta\left(\frac{dR}{dv}\right)\right\} \tag{24}$$

$$\frac{d\delta_2 r}{dt} = an\left\{-e^2 + e\cos(nt-\omega) + e^2\cos 2(nt-\omega)\right\}\delta v \tag{25}$$

$$\frac{d\delta r}{dt} = \frac{d\delta_0 r}{dt} + \frac{d\delta_1 r}{dt} + \frac{d\delta_2 r}{dt} \tag{26}$$

$$\frac{d\delta_0 v}{dt} = -\frac{1}{a^2}\left\{1 + \tfrac{1}{2}e^2 + 2e\cos(nt-\omega) + \tfrac{5}{2}e^2\cos 2(nt-\omega)\right\}\int\left(\frac{dR}{dv}\right)dt \tag{27}$$

$$\frac{d\delta_1 v}{dt} = -2\frac{n}{a}\left\{1 + e^2 + 3e\cos(nt-\omega) + \tfrac{9}{2}e^2\cos 2(nt-\omega)\right\}\delta r \tag{28}$$

$$\frac{d\delta v}{dt} = \frac{d\delta_0 v}{dt} + \frac{d\delta_1 v}{dt} \tag{29}$$

In equation (24) we must use

$$c_1\cos\beta = \{1-\tfrac{1}{2}e^2\}\cos nt + e\cos(2nt-\omega) - e\cos\omega + \tfrac{9}{8}e^2\cos(3nt-2\omega) \mp \tfrac{1}{8}e^2\cos(nt-2\omega) \tag{30}$$

$$c_2\cos\beta = \alpha^2\,ndt\left\{\mp\{1-\tfrac{3}{2}e^2\}\cos nt \mp e\cos(2nt-\omega) \pm e\cos\omega \mp \tfrac{9}{8}e^2\cos(3nt-2\omega) + \tfrac{1}{8}e^2\cos(nt-2\omega)\right\} \tag{31}$$

$$c_3\sin\beta = 2a\,ndt\left\{\{1-e^2\}\sin nt + \tfrac{5}{4}e\sin(2nt-\omega) - \tfrac{1}{4}e\sin\omega + \tfrac{13}{8}e^2\sin(3nt-2\omega) \pm e^2\sin(nt-2\omega)\right\} \tag{32}$$

If in equations (30–32) we mutually interchange *sin* and *cos*, and use the lower signs where two are given, we shall obtain the values of the factors in the last term of equation (24).

8. It is now easy to find the following values:

$$c_2\cos\beta\left(\frac{dR}{dr}\right) = \tfrac{1}{2}\overline{m}^2\,ndt\left\{\begin{matrix}\pm\{1.88930 - 17.00367\,e^2\}\cos(3nt-2n''t) + \{1.88930 - 1.88930\,e^2\}\cos(nt-2n''t) \\ \pm e(4.72325)\cos(4nt-2n''t-\omega) + e(0.94465)\cos(2nt-2n''t-\omega) \pm e(6.61254)\cos(2nt-2n''t+\omega) \\ \pm e(2.83394)\cos(2n''t-\omega) \pm e^2(8.73800)\cos(5nt-2n''t-2\omega) + e^2(0.70848)\cos(3nt-2n''t-2\omega) \\ \pm e^2(0.23616)\cos(nt+2n''t-2\omega) \pm e^2(7.32103)\cos(nt-2n''t+2\omega)\end{matrix}\right\} \tag{33}$$

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$$
(34)\quad c_3 \sin\beta\left(\frac{dR}{dv}\right) = \tfrac{1}{3}\,\overline{m}^2\, n dt \Big\{ \pm \{3.77859 - 28.33942\, e^2\} \cos(3nt - 2n''t) + \{3.77859 - 5.66788\, e^2\} \cos(nt - 2n''t)
\pm e\,(8.50183) \cos(4nt - 2n''t - \omega) + e\,(2.83394) \cos(2nt - 2n''t - \omega) \pm e\,(12.28042) \cos(2nt - 2n''t + \omega)
\pm e\,(6.61253) \cos(2n''t - \omega) \pm e^2\,(14.64204) \cos(5nt - 2n''t - 2\omega) + e^2\,(2.36162) \cos(3nt - 2n''t - 2\omega)
\pm e^2\,(1.41698) \cos(nt + 2n''t - 2\omega) \pm e^2\,(11.80810) \cos(nt - 2n''t + 2\omega) \Big\}
$$

If we now take the integral of the sum of these two equations we get

$$
\int \left\{ c_2 \cos\beta\left(\frac{dR}{dr}\right) + c_3 \sin\beta\left(\frac{dR}{dv}\right) \right\} =
$$

$$
(35)\quad = \tfrac{1}{2}\,\overline{m}^2 \Big\{ - \{0.632422 - 3.79454\, e^2\} \sin(3nt - 2n''t) \pm \{5.74028 - 7.65371\, e^2\} \sin(nt - 2n''t)
- e\,(0.947634) \sin(4nt - 2n''t - \omega) \pm e\,(1.90128) \sin(2nt - 2n''t - \omega) + e\,(2.85192) \sin(2nt - 2n''t + \omega)
- e\,(748.997) \sin(2n''t - \omega) - e^2\,(1.18380) \sin(5nt - 2n''t - 2\omega) \pm e^2\,(1.02769) \sin(3nt - 2n''t - 2\omega)
+ e^2\,(1.63255) \sin(nt + 2n''t - 2\omega) - e^2\,(4.54439) \sin(nt - 2n''t + 2\omega) \Big\}
$$

In finding this integral, we have supposed that $n'' = 0.00630628\, n$, and if we use the lower sign where two are given, and change *sin* to *cos* in the second member, we shall have the value of

$$
\int \left\{ c_2 \sin\beta\left(\frac{dR}{dr}\right) + c_3 \cos\beta\left(\frac{dR}{dv}\right) \right\}
$$

If we now substitute the proper values in equation (24), we get

$$
(36)\quad \frac{d\delta_1 r}{dt} = \frac{a\overline{m}^2}{2\mu}\, n \Big\{ \{5.10786 + 736.883\, e^2\} \sin 2(nt - n''t) + e\,(7.32635) \sin(3nt - 2n''t - \omega)
+ e\,(745.477) \sin(nt - 2n''t + \omega) + e^2\,(9.22967) \sin(4nt - 2n''t - 2\omega) + e^2\,(753.751) \sin 2(n''t - \omega) \Big\}
$$

Equation (22) gives

$$
(37)\quad \int\left(\frac{dR}{dv}\right) dt = \frac{\overline{m}^2}{2an} \Big\{ - \{1 - \tfrac{5}{2}e^2\}(1.901284) \cos 2(nt - n''t) - e\,(1.264847) \cos(3nt - 2n''t - \omega)
+ e\,(11.48057) \cos(nt - 2n''t + \omega) - e^2\,(0.947635) \cos(4nt - 2n''t - 2\omega) + e^2\,(748.9977) \cos 2(n''t - \omega) \Big\}
$$

Substituting this in equation (23), we get

$$
(38)\quad \frac{d\delta_0 r}{dt} = \frac{a\overline{m}^2}{2\mu}\, n \Big\{ e^2\,(6.37270) \sin 2(nt - n''t) - e\,(0.95064) \sin(3nt - 2n''t - \omega)
+ e\,(0.95064) \sin(nt - 2n''t + \omega) - e^2\,(1.58306) \sin(4nt - 2n''t - 2\omega) + e^2\,(4.78964) \sin 2(n''t - \omega) \Big\}
$$

If we also substitute (37) in (27), we get

$$
(39)\quad \frac{d\delta_0 v}{dt} = \frac{a\overline{m}^2}{2\mu}\, n \Big\{ \{1.90128 - 14.01829\, e^2\} \cos 2(nt - n''t) + e\,(3.16612) \cos(3nt - 2n''t - \omega)
- e\,(9.57929) \cos(nt - 2n''t + \omega) + e^2\,(4.58908) \cos(4nt - 2n''t - 2\omega) - e^2\,(758.102) \cos 2(n''t - \omega) \Big\}
$$

Since $\delta_2 r$ depends upon δv, and $\delta_1 v$ depends upon δr, we can only find these quantities by successive approximations. The first approximation to value of δr is equal to the part of $\delta_1 r$ in equation (36), which is independent of the eccentricity e of the moon's orbit. Whence we find

$$
(40)\quad \textit{1st value of}\ \ \delta r = -\frac{a\overline{m}^2}{2\mu}\,(2.57014) \cos 2(nt - n''t)
$$

Then equation (29) gives for the first approximate value of δv

$$
\delta v = \frac{\overline{m}^2}{2\mu}\,(3.54312) \sin 2(nt - n''t) \qquad (41)
$$

Equation (25) then gives

$$
(42)\quad \frac{d\delta_2 r}{dt} = \frac{a\overline{m}^2}{2\mu}\, n \Big\{ e(1.77156)\left[\sin(3nt - 2n''t - \omega) + \sin(nt - 2n''t + \omega)\right] \Big\}
$$

Then the substitution in equation (26) gives the second approximation to the value of $\frac{d\delta r}{dt}$ as follows:

$$
(43)\quad \frac{d\delta r}{dt} = \frac{a\overline{m}^2}{2\mu}\, n \Big\{ (5.10786) \sin 2(nt - n''t) + e\,(8.14727) \sin(3nt - 2n''t - \omega) + e\,(748.200) \sin(nt - 2n''t + \omega) \Big\}
$$

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The integral of this equation, being substituted in equation (28), will give the second approximation to the value of $\frac{d\delta_1 v}{dt}$; and this being added to equation (39) will give the second approximation to the value δv. We shall therefore have, after three approximations,

$$\frac{d\delta_2 r}{dt} = \frac{a\overline{m}^2}{2\mu} n \Big\{ e^2(765.680) \sin 2(nt - n''t) + e\,(1.77156) \sin (3nt - 2n''t - \omega) + e\,(1.77156) \sin (nt - 2n''t + \omega) + e^2\,(4.50488) \sin (4nt - 2n''t - 2\omega) - e^2\,(768.262) \sin 2(n''t - \omega) \Big\} \tag{44}$$

$$\frac{d\delta_1 v}{dt} = \frac{\overline{m}^2}{2\mu} n \Big\{ \{5.14028 + 3805.105\, e^2\} \cos 2(nt - n''t) + e\,(13.16486) \cos (3nt - 2n''t - \omega) + e\,(1523.224) \cos (nt - 2n''t + \omega) + e^2\,(25.84225) \cos (4nt - 2n''t - 2\omega) + e^2\,(743.317) \cos 2(n''t - \omega) \Big\} \tag{45}$$

Then we get for the complete values of the differentials of δr and δv,

$$\frac{d\delta r}{dt} = \frac{a\overline{m}^2}{2\mu} n \Big\{ \{5.10786 + 1508.936\, e^2\} \sin 2(nt - n''t) + e\,(8.14727) \sin (3nt - 2n''t - \omega) + e\,(748.200) \sin (nt - 2n''t + \omega) + e^2\,(12.15149) \sin (4nt - 2n''t - 2\omega) - e^2\,(9.721) \sin 2(n''t - \omega) \Big\} \tag{46}$$

$$\frac{d\delta v}{dt} = \frac{\overline{m}^2}{2\mu} n \Big\{ \{7.04156 + 3791.087\, e^2\} \cos 2(nt - n''t) + e\,(16.33098) \cos (3nt - 2n''t - \omega) + e\,(1513.645) \cos (nt - 2n''t + \omega) + e^2\,(30.43133) \cos (4nt - 2n''t - 2\omega) - e^2\,(14.785) \cos 2(n''t - \omega) \Big\} \tag{47}$$

Equations (46) and (47) give by integration

$$\delta r = \frac{a\overline{m}^2}{2\mu} \Big\{ - \{2.57014 + 759.256\, e^2\} \cos 2(nt - n''t) - e\,(2.72722) \cos (3nt - 2n''t - \omega) - e\,(757.757) \cos (nt - 2n''t + \omega) - e^2\,(3.04748) \cos (4nt - 2n''t - 2\omega) + e^2\,(770.760) \cos 2(n''t - \omega) \Big\} \tag{48}$$

$$\delta v = \frac{\overline{m}^2}{2\mu} \Big\{ \{3.54313 + 1907.57\, e^2\} \sin 2(nt - n''t) + e\,(5.46664) \sin (3nt - 2n''t - \omega) + e\,(1532.98) \sin (nt - 2n''t + \omega) + e^2\,(7.6319) \sin (4nt - 2n''t - 2\omega) - e^2\,(1172.31) \sin 2(n''t - \omega) \Big\} \tag{49}$$

If we assume the earth's mass to be $1 \div 335172$ of the sun's mass, and use BESSEL's mass of *Jupiter*, we shall find $m'' = 319.8574$; and if we take the moon's mean distance from the earth as unity, we shall find $a'' = 2021.517$. Therefore equation (20) will give $\overline{m}^2 = 0''.0079864$; and if the moon's mass be taken as $1 \div 80$ of the earth's mass we shall have $\mu = \frac{81}{80}$, and

$$\frac{\overline{m}^2}{\mu} = 0''.0078803 \tag{50}$$

Then since $e = 0.0548993$ we shall find that equation (49) gives

$$\delta v = 0''.0366 \sin 2(nt - n''t) + 0''.0012 \sin (3nt - 2n''t - \omega) + 0''.3319 \sin (nt - 2n''t + \omega) + 0''.0001 \sin (4nt - 2n''t - 2\omega) - 0''.0139 \sin 2(n''t - \omega) \tag{51}$$

(*To be continued.*)

THE VARIABLE STARS *T* AND *U MONOCEROTIS*, 1886.

BY EDWIN F. SAWYER.

T Monocerotis 2279

Fifty-six observations were obtained on this star, extending from 1885 November 14, to 1886 April 19. From these the following epochs of maxima and minima have been deduced, in Cambridge M.T., using the mean light-curve formed from the 1881–83 observations:

OBSERVED MAXIMA		d	h	m	OBSERVED MINIMA		d	h	m
1885	Dec.	1	17	48	1885	Dec.	17	13	19
		28	4	0	1886	Jan.	13	17	26
1886	Jan.	23	15	15		Feb.	7	20	54
	Feb.	18	23	34		Mar.	8	15	51
	Mar.	18	23	7		Apr.	6	1	54
	Apr.	16	17	21					

Cambridgeport, 1887 *May* 2.

U Monocerotis 2676

This star was observed on 49 evenings, from 1885 November 28, to 1886 April 29. From these observations the following times of maxima and minima have been determined:

Maximum = 1886	Jan.	13.5	Light =	25.1
	Feb.	24.0		25.1
	April	14.0		26.6
Minimum = 1885	Dec.	25.8	Light =	7.3
1886	Feb.	3.0		13.2
	March	28.0		6.3

The interval between the 1st and 2d maximum = 41.5 days; and between the 2d and 3d maximum = 49 days. The interval between the 1st and 2d minimum = 39.2 days; and between the 2d and 3d minimum = 53 days. The 1st and 3d minima were faint ones, while the 2d was a bright one.

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OBSERVATIONS OF THE COMET 1886 VII

MADE AT THE PRINCETON (N. J.) OBSERVATORY

(Communicated by the Director, PROF. C. A. YOUNG.)

Greenw. M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			1. *With ring-micrometer and the 9½-inch equatorial. M. McNeill, Observer.*					
h m s			m s	′ ″	h m s	° ′ ″		
1886 Dec. 16 10 57 2	1	6	−0 54.26	+20 48.4	22 32 23.77	−10 15 35.8	n9.126	n0.830
11 18 46	2	6	−1 39.50	−18 31.1	22 32 29.45	−10 14 54.4	n9.242	n0.827
20 10 49 12	3	3	−2 31.23	−13 37.8	22 52 58.97	− 7 53 43.7	n9.036	n0.816
10 51 35	4	4	−2 52.58	−19 44.0	22 52 59.75	− 7 53 48.2	n9.054	n0.816
11 16 27	5	8	−0 41.99	+ 6 55.0			n9.202	n0.814
21 11 9 13	6	12	−0 18.84	+ 0 51.1	22 58 11.13	− 7 17 2.6	n9.159	n0.810
25 10 59 2	7	5	−0 51.03	+20 59.7			n9.064	n0.794
11 16 9	8	5	+0 22.81	−16 57.5			n9.171	n0.793
27 11 12 15	9	12	+1 35.76	+ 2 24.1	23 28 41.66	− 3 36 4.0	n9.140	n0.784
			2. *With the filar-micrometer of the 23-inch equatorial. C. A. Young, Observer.*					
1886 Dec. 21 11 3 37	6	10		+ 0 41.6		− 7 17 12.1		n0.811
11 4 33	6	8	−0 19.19		22 58 10.78		n9.132	
27 11 16 4	9	5		+ 2 37.9		− 3 35 50.2		n0.785
1887 Jan. 15 11 0 16	10	8		+ 8 45.1		+ 7 26 3.5		n0.682
11 12 39	10	8	+0 16.06		0 59 21.73		n9.066	
21 12 40 39	11	10		+ 6 55.4		+10 25 11.5		n0.811
12 57 15	11	10	+0 5.82		1 25 49.62		n9.462	
22 12 49 54	12	3	−0 39.24		1 29 58.33		n9.447	
25 13 10 52	13	12	−0 4 26		1 42 36.97		n9.493	
13 29 46	13	11		− 9 8.4		+12 12 49.7		n0.663
27 13 21 17	14	16	+0 2.25		1 50 46.64		n9.514	
13 41 24	14	10		+ 0 18.4		+13 3 24.2		n0.660
Feb. 12 12 26 28	15	10		− 0 51.9				n0.555
12 43 6	15	10	+0 39.49				n9.447	
19 12 48 54	16	5	+0 23.21		3 14 51.89		n9.475	

Mean Places for 1886.0 of Comparison–Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	22 33 16.04	+1.99	−10 36 39.2	+15.0	Astr. Nach. 81, p. 75, no. 417
2	22 34 6.95	+2.00	− 9 56 38.5	+15.2	½(Astr. Nach. 94.295 + Schj. 9271,2)
3	22 55 28.15	+2.05	− 7 40 21.2	+15.3	½(Astr. Nach. 57.230 + Schj. 9451)
4	22 55 50.27	+2.06	− 7 34 19.5	+15.3	Weisse's Bessel XXII, 1136
5	22 52.3		− 8 9		On Peters's Chart No. 19
6	22 58 27.91	+2.06	− 7 18 8.9	+15.2	½(Schj. 9475 + Y. 10151)
9	23 27 3.71	+2.19	− 3 38 43.7	+15.6	Schj. 9709
10	0 59 3.06	+2.61	+ 7 17 4.3	+14.1	Yarnall 554
11	1 25 41.04	+2.76	+10 18 2.9	+13.2	Yarnall 714
12	1 30 34.78	+2.79	+10 47 16.6	+13.1	DM. 10° 210
13	1 42 38.37	+2.86	+12 21 45.4	+12.7	DM. 12° 236
14	1 50 41.50	+2.89	+13 2 53.5	+12.3	DM. 12° 254
16	3 14 25.43	+3.25	+20 14 4.6	+ 7.2	B.B. VI, 20° 541

The stars nos. 7, 8, 15 have not been identified; the two former are 9ᴹ.5, the latter is 10ᴹ.

On Dec. 27 the $\Delta\alpha$ was too great to be measured with the micrometer-screw, and it was not practicable to take transits, as the chronograph was temporarily out of order.

On Jan. 22 and Feb. 19 it became foggy before the observations could be completed.

Prof. Boss, of the Dudley Observatory, will re-observe the comparison-stars.

Observations are corrected for refraction and proper-motion of comet.

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OBSERVATIONS OF COMET 1887 *e* (*Barnard, May 12*)

MADE AT THE HARVARD COLLEGE OBSERVATORY

BY O. C. WENDELL, ASSISTANT.

(Communicated by Prof. EDWARD C. PICKERING, Director.)

1887 Greenwich M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
May 13 15 15 43	1	5	+1 11.20	−3 41.1	15 12 16.43	−30 7 23.3	*n*9.209	0.916
14 15 22 22	2	5	+1 0.32	+4 7.1	15 13 53.79	−29 35 17.8	*n*9.153	0.917
19 15 58 36	3	4	+0 49.91	+5 35.3	15 22 24.85	−26 37 53.7	*n*8.592	0.915
25 15 20 58	4	5	+1 17.12	+6 46.2	15 33 25.33	−22 33 53.1	*n*8.951	0.900
30 14 36 31	5	5	+1 6.34	+2 4.7	15 43 16.26	−18 49 56.0	*n*9.187	0.881

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 11 3.00	+2.23	−30 3 40.5	−1.7	Cordoba Zones, 15ʰ.714
2	15 12 51.24	+2.23	−29 39 23.2	−1.7	Cordoba Zones, 15ʰ.821
3	15 21 32.78	+2.16	−26 43 27.6	−1.4	Cordoba Zones, 15ʰ.1425
4	15 32 6.06	+2.15	−22 40 38.4	−0.9	Oe. Argel. 14722
5	15 42 7.82	+2.10	−18 52 0.6	−0.1	Oe. Argel. 14900

TWO HUNDRED SIXTY-EIGHTH ASTEROID.

A cable dispatch received June 11, by the *Science Observer* code, gives notice of the discovery of a small planet of the twelfth magnitude, by BORRELLY, at Marseilles.

The position was roughly given as

$\alpha = 17^h\,19^m \qquad \delta = -20°\,38'$

RING-MICROMETER OBSERVATIONS OF COMET 1887 *e* (*Barnard, May 12*)

MADE AT THE VANDERBILT UNIVERSITY OBSERVATORY

BY E. E. BARNARD.

1887 Nashville M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
May 12 11 10 11	1	9	−0 58.96	+11 52.8	15 10 49.20	−30 35 50.1		
13 10 28 43	2	10	+1 16.18	− 2 23.2	15 12 21.14	−30 6 6.3		
14 10 28 57	3	7	+2 58.76	+10 1.1	15 13 58.19	−29 33 59.4		
14 12 2 51	3	5	+3 4.13	+11 53.6	15 14 3.56	−29 32 6.9		
18 11 58 12	4	7	−0 37.07	+ 1 18.6	15 20 47.88	−27 12 39.1		
24 10 59 58	5	12	+1 1.71	+ 1 18.9	15 31 36.03	−23 15 19.0		
25 10 17 35	6	15	+0 45.03	+14 6.5	15 33 29.72	−22 32 41.8		
25 10 37 28	7	9	+0 23.06	− 0 47.1	15 33 30.88	−22 32 11.3		
26 11 47 21	8	6	+4 35.24	− 1 32.6	15 35 32.28	−21 46 34.9		
28 12 40 14	9	9	−1 15.93	− 7 39.8				
June 9 11 25 19	10	2	−1 17.76	+ 2 55.0				
9 11 36 36	11	4	+1 13.32	− 1 4.2				
10 10 56 41	12	7	−1 4.68	+ 1 47.0				
11 11 41 56	13	6	+0 39.79	+ 8 57.0				
16 11 19 9	14	14	+0 50.17	+ 1 2.3				
17 10 6 40	15	5	−0 11.81	+14 26.4				
17 10 19 40	16	9	−0 31.67	+15 13.1				
18 9 24 10	17	9	−1 28.25	− 2 3.2				
18 9 26 50	18	8	+0 4.11	+ 8 18.1				
20 9 55 28	19	7	−2 3.51	− 7 52.4				
23 10 4 43	20	9	+3 19.66	− 7 24.8				

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Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 11 45.92	+2.24	−30 47 41.3	−1.6	Gould and Stone
2	15 11 2.73	2.23	30 3 41.3	1.8	Yarnall 6275
3	15 10 57.21	2.22	29 43 58.6	1.9	" 6274
4	15 21 22.78	2.17	27 13 55.8	1.9	Gould Z.C. 1415
5	15 30 32.18	2.14	23 16 37.0	0.9	" " 2061
6	15 32 42.54	2.15	22 46 47.4	0.9	Yarnall 6444
7	15 33 5.67	2.15	22 31 23.4	0.8	" 6447
8	15 30 54.94	2.10	21 45 1.3	1.0	" 6425
9	15 40 37	2.08	20 5	−0.4	8th Mag. Equatorial
10	16 6 9	2.09	10 54	+1.9	" "
11	16 3 38	2.09	10 50	1.9	" "
12	16 8 4	2.09	10 6	2.2	" "
13	16 8 39	2.08	9 26	3.4	" "
14	16 19 28	2.05	5 36	3.7	" "
15	16 23 30	2.05	5 11	4.0	" "
16	16 23 9	2.05	5 11	4.0	" "
17	16 26 16	2.05	4 14	4.3	9th Mag. "
18	16 24 45	2.05	4 24	4.3	8th Mag. "
19	16 31 27	2.07	2 48	4.9	" "
20	16 32 53	+2.07	− 0 55	+5.4	" "

Vanderbilt University Observatory, Nashville, Tenn., 1887 *June* 21.

OBSERVATIONS OF OCCULTATIONS OF STARS BY THE MOON

MADE AT THE LEANDER McCORMICK OBSERVATORY, UNIVERSITY OF VIRGINIA.

[Communicated by the Director, PROF. O. STONE.]

Date	Star	Phenomenon	Moon's Limb	Time Noted	Clock Cor.	Sidereal Time	Instrument	Power	Obs.
				h m s	m s	h m s			
1885 Dec. 22	W. VII., 685	Immersion	Bright	4 20 49.7	+1 9.5	4 21 59.2	66cm	350	L
1886 Feb. 13	111 Tauri	Immersion	Dark	5 7 25.2	+3 4.7	5 10 29.9	10cm	150	M
15	W. VII., 685	Immersion	Dark	7 13 6.7	+3 8.3	7 16 25.0	10cm	150	M
21	l_1 Virginis	Immersion	Bright	9 57 48.0	+3 20.1	10 1 8.1	66cm	175	M
21	l_1 Virginis	Emersion	Dark	10 49 35.2	+3 20.2	10 52 55.4	66cm	175	M
Apr. 8	B.A.C. 1526	Immersion	Dark	11 6 41.4	−2 6.8	11 4 34.6	66cm	250	M

Dec. 22.—Moon almost full; estimated $0^s.1$ late.
Feb. 13.—Instantaneous. Moon near Zenith.
Feb. 15.—Time noted by eye and ear.
Feb. 21.—Immersion rather poor. Emersion estimated $1^s.0$ late.
Apr. 8.—Observations good. Moon near horizon.

Observations for time were made on the night of the occultation, except on Feb. 15. The timepiece used was the sidereal chronometer Bond (332), except on Apr. 8, when the sidereal clock Parkinson and Frodsham was used.

L = F. P. Leavenworth; M = Frank Muller.

CORRIGENDUM.

No. 157, BARNARD's observations, comparison-star no. 1, for $15^h\ 11^m\ 4^s.5$ put $15^h\ 11^m\ 45^s$.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

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ON CERTAIN INEQUALITIES IN THE MOON'S MOTION ARISING FROM THE ACTION OF THE PLANETS.

BY JOHN N. STOCKWELL.

(*Continued from page* 109.)

9. The preceding calculations have been made according to the method which was developed and employed in the author's "*Theory of the Moon's Motion*;" but in order to leave no uncertainty as to the correctness of the results which we have obtained, we shall here give the solution of the problem according to LAPLACE's method, as explained in book II of the *Mécanique Céleste*.

LAPLACE gives the following formulas for the determination of δr, δv and $\mathrm{d}R$:

$$\delta r = \frac{a\cos v\int ndt\, r\sin v\left\{2\int \mathrm{d}R + r\left(\frac{dR}{dr}\right)\right\} - a\sin v\int ndt\, r\cos v\left\{2\int \mathrm{d}R + r\left(\frac{dR}{dr}\right)\right\}}{\mu(1-e^2)^{\frac{1}{2}}} \tag{52}$$

$$\delta v = \frac{\dfrac{2rd\delta r + dr\delta r}{a^2ndt} + \dfrac{3a}{\mu}\int\int ndt\,\mathrm{d}R + \dfrac{2a}{\mu}\int ndt\, r\left(\dfrac{dR}{dr}\right)}{(1-e^2)^{\frac{1}{2}}} \tag{53}$$

$$\mathrm{d}R = \left(\frac{dR}{dr}\right)dr + \left(\frac{dR}{dv}\right)dv \tag{54}$$

We also have

$$\begin{aligned} dr &= andt\,\{e\sin(nt-\omega) + e^2\sin 2(nt-\omega)\} \\ dv &= ndt\,\{1 + 2e\cos(nt-\omega) + \tfrac{5}{2}e^2\cos 2(nt-\omega)\} \\ \begin{matrix}\sin\\ \cos\end{matrix}\, v &= (1-e^2)\begin{matrix}\sin\\ \cos\end{matrix}\, nt + e\begin{matrix}\sin\\ \cos\end{matrix}\,(2nt-\omega) - e\begin{matrix}\sin\\ \cos\end{matrix}\,\omega \\ &\quad + \tfrac{9}{8}e^2\begin{matrix}\sin\\ \cos\end{matrix}\,(3nt-2\omega) \pm \tfrac{1}{8}e^2\begin{matrix}\sin\\ \cos\end{matrix}\,(nt-2\omega) \end{aligned} \tag{55}$$

Equation (54) gives by means of (21), (22) and (55)

$$\begin{aligned} 2\int \mathrm{d}R = \frac{\overline{m}^2}{2a}\Big\{ &-\{3.802568 - 9.50642\,e^2\}\cos 2(nt-n''t) - e\,(3.794545)\cos(3nt-2n''t-\omega) \\ &+ e\,(11.48058)\cos(nt-2n''t+\omega) - e^2\,(3.790541)\cos(4nt-2n''t-2\omega)\Big\} \end{aligned} \tag{56}$$

Equations (21) and (13) give

$$\begin{aligned} r\left(\frac{dR}{dr}\right) = \frac{\overline{m}^2}{2a}\Big\{ &-\{3.77859 - 9.44647\,e^2\}\cos 2(nt-n''t) - e\,(3.77859)\cos(3nt-2n''t-\omega) \\ &+ e\,(11.33577)\cos(nt-2n''t+\omega) - e^2\,(3.77859)\cos(4nt-2n''t-2\omega) - e^2\,(9.44648)\cos 2(n''t-\omega)\Big\} \end{aligned} \tag{57}$$

The substitution of these quantities in equation (52) gives

$$\begin{aligned} \delta r = a\frac{\overline{m}^2}{2\mu}\Big\{ &-\{2.57014 + 759.0552\,e^2\}\cos 2(nt-n''t) - e\,(2.72723)\cos(3nt-2n''t-\omega) \\ &- e\,(757.7556)\cos(nt-2n''t+\omega) - e^2\,(3.04750)\cos(4nt-2n''t-2\omega) + e^2\,(770.5978)\cos 2(n''t-\omega)\Big\} \end{aligned} \tag{58}$$

If we now multiply equation (56) by $\frac{3}{2}\frac{a}{\mu}ndt$ and take the integral, we get

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$$(59)\qquad \tfrac{3}{2}\frac{a}{\mu}\int\!\!\int ndt\,dR = \frac{\overline{m}^2}{2\mu}\Big\{ -\{2.870025 - 7.175063\,e^2\}\sin 2(nt-n''t) - e\,(1.905282)\sin(3nt-2n''t-\omega) + e\,(17.44084)\sin(nt-2n''t+\omega) - e^2\,(1.425949)\sin(4nt-2n''t-2\omega)\Big\}$$

Also if we multiply equation (57) by $\frac{2a}{\mu}ndt$ and take the integral, we get

$$(60)\qquad \frac{2a}{\mu}\int ndt\, r\left(\frac{dR}{dr}\right) = \frac{\overline{m}^2}{2\mu}\Big\{ -\{3.802569 - 9.506415\,e^2\}\sin 2(nt-n''t) - e\,(2.529695)\sin(3nt-2n''t-\omega) + e\,(22.96113)\sin(nt-2n''t+\omega) - e^2\,(1.895271)\sin(4nt-2n''t-2\omega) - e^2\,(1497.993)\sin 2(n''t-\omega)\Big\}$$

If we take the differential of equation (58) we get

$$(61)\qquad \frac{d\delta r}{dt} = a\frac{\overline{m}^2}{2\mu}n\Big\{ \{5.107865 + 1508.537\,e^2\}\sin 2(nt-n''t) + e\,(8.14730)\sin(3nt-2n''t-\omega) + e\,(748.1986)\sin(nt-2n''t+\omega) + e^2\,(12.15157)\sin(4nt-2n''t-2\omega) - e^2\,(9.718907)\sin 2(n''t-\omega)\Big\}$$

From the first of equations (13) and equation (61) we get

$$(62)\qquad \frac{2rd\delta r}{a^2ndt} = \frac{\overline{m}^2}{2\mu}\Big\{ \{10.21573 + 2265.836\,e^2\}\sin 2(nt-n''t) + e\,(11.18674)\sin(3nt-2n''t-\omega) + e\,(1491.289)\sin(nt-2n''t+\omega) + e^2\,(13.60191)\sin(4nt-2n''t-2\omega) + e^2\,(731.3147)\sin 2(n''t-\omega)\Big\}$$

Equation (58) and the first of (55) give

$$(63)\qquad \frac{dr\delta r}{a^2ndt} = \frac{\overline{m}^2}{2\mu}\Big\{ -e\,(1.28507)\sin(3nt-2n''t-\omega) + e\,(1.28507)\sin(nt-2n''t+\omega) - e^2\,(377.514)\sin 2(nt-n''t) - e^2\,(2.64868)\sin(4nt-2n''t-2\omega) - e^2\,(380.1629)\sin 2(n''t-\omega)\Big\}$$

If we now substitute the values of the functions we have computed, in equation (53) we find after dividing by $(1-e^2)^{\frac{1}{2}}$

$$(64)\qquad \delta v = \frac{\overline{m}^2}{2\mu}\Big\{ \{3.54314 + 1906.775\,e^2\}\sin 2(nt-n''t) + e\,(5.46669)\sin(3nt-2n''t-\omega) + e\,(1532.976)\sin(nt-2n''t+\omega) + e^2\,(7.63206)\sin(4nt-2n''t-2\omega) - e^2\,(1146.841)\sin 2(n''t-\omega)\Big\}$$

Equations (58) and (64) are practically identical with equations (48) and (49), which proves that no mistake of importance has been committed in the application of the formulas. LAPLACE's method, however, has the advantage of not requiring the use of so many decimals in order to obtain an accurate result, and hence the value of δv in equation (64) is slightly more accurate than in equation (49).

10. The preceding values of δr and δv arise from the direct action of *Jupiter*, and in order to complete the subject of these inequalities, we must now determine the effect of *Jupiter's* indirect action. The amount by which a planet changes the solar perturbations of the moon, is called the planet's indirect action on the moon.

In the theory of the moon's motion the only term in which the indirect action of *Jupiter* can produce any inequalities of the form which we have been considering, is the following, in which m', r' and v' denote the sun's mass, distance and longitude,

$$R = -\tfrac{3}{4}\frac{m'r^2}{r'^3}\cos 2(v-v') \qquad (65)$$

This gives

$$(66)\qquad \delta R = \tfrac{9}{4}\frac{m'r^2}{r'^4}\cos 2(v-v')\,\delta r' - \tfrac{3}{2}\frac{m'r^2}{r'^3}\sin 2(v-v')\,\delta v'$$

If we increase the coefficients of the inequalities of the earth's radius vector and longitude as given by LAPLACE in the third volume of the *Mécanique Céleste*, in the ratio of 1067.09 to 1047.879, so as to correspond to BESSEL's mass of *Jupiter*, we shall get the following values of $\delta r'$ and $\delta v'$, in which we have changed $n''t$ to v' and $n'''t$ to v'', which is permissible since the orbits are supposed to be circular.

$$(67)\qquad \begin{aligned}\frac{\delta r'}{a'} &= -0.00000966377\cos 2(v'-v'')\\ \delta v' &= +0.0000137704\sin 2(v'-v'')\end{aligned}$$

Substituting these values in equation (66) and puttting $r'=a'$, we get

$$\delta R = -\frac{m'r^2}{a'^3}(0.00000054395)\cos 2(v-v'') \qquad (68)$$

If we substitute the value of f^{-3} given by equation (19) in equation (11) we shall get

$$R = -\frac{m''r^2}{a''^3}(0.944648)\cos 2(v-v'') \qquad (69)$$

Equations (68) and (69) give

$$\delta R = \tfrac{1}{11.78}R \qquad (70)$$

Therefore, the effect of *Jupiter's* indirect action on the moon is to increase its direct action by its *twelfth* part very nearly.

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11. If we increase the coefficients of the two inequalities which have been investigated by NEISON and HILL, and which we have given in equation (51), by their *twelfth part*, we shall obtain the following values of these inequalities:

$$\delta v = +\,0''.360 \sin(nt - 2n''t + \omega) - 0''.015 \sin 2(n''t - \omega) \tag{71}$$

If we reduce the arguments to the same form and notation, Mr. HILL's equation will become

$$\delta v = -\,0''.903 \sin(nt - 2n''t + \omega) - 0''.209 \sin 2(n''t - \omega) \tag{72}$$

The coefficient of the long-period inequality in Mr. HILL's equation is about fourteen times as great as in equation (71), while the coefficient of the evection term is nearly two and one-half times larger, and has a contrary sign. The last terms of both equations, however, are so small as to be of no practical importance, although, as a question of theory, a closer agreement would seem to be very desirable. The agreement of the two solutions given in this paper would seem to justify the conclusion that no mistakes have been committed in the substitution of the expressions for the forces in the formulas for the perturbations; and, therefore, if the results here given are erroneous, the error must exist in the expressions of the forces themselves. But great care has been taken in the computation of the forces, and a comparison of the expressions here given with analogous ones due to solar attraction, leads to the belief that the expressions of the forces are correct.

12. On the other hand, there are some considerations connected with Mr. HILL's work which would seem to justify the suspicion of possible errors, and I may be permitted to briefly call attention to them, hoping that he may be thereby induced to re-examine his calculations.

In the first place, he gives for the expression of the forces depending on the direct action of the planet

$$R = m'\frac{a^2}{a''^3}\left\{ 2''.732\, e^2 \cos 2(n''t - \omega) + 0''.0025\, e^2 \sin 2(n''t - \omega) \right\} \tag{73}$$

in which we have retained only the terms of lowest order in the expressions of the coefficients. For the terms due to the indirect action he finds

$$\delta R = m'\frac{a^2}{a''^3}\left\{ 0''.267\, e^2 \cos 2(n''t - \omega) - 0''.006\, e^2 \sin 2(n''t - \omega) \right\} \tag{74}$$

In comparing the coefficients of the first terms of these expressions, Mr. HILL remarks that "the indirect action augments the direct by a tenth part only." But if we extend the comparison to the second terms we find that the indirect action is nearly two and one-half times larger than the direct, and that it also has a contrary sign; and hence the effect of the indirect action on the second term is twenty-five times greater than on the first. According to equation (70) the ratio of the direct action to the indirect is the same for all the terms.

And, in the second place, it is easy to prove that the coefficient of the evection term in Mr. HILL's equation (72) is totally erroneous, unless the action of *Jupiter* on the moon is repulsive instead of attractive. For the evection due to the sun's attraction, according to DELAUNAY, is, very nearly,

$$\delta v = +\,4600'' \sin(nt - 2n't + \omega) \tag{75}$$

The evection due to *Jupiter* according to Mr. HILL is

$$\delta v = -\,0''.903 \sin(nt - 2n''t + \omega) \tag{76}$$

Now by reason of the great distances of the sun and planets it follows that whenever the arguments of the two preceding equations are equal, or, in other words, when the sun and planet are in conjunction at the earth, they are also in conjunction at the moon; their lines of action are therefore sensibly parallel, and consequently their action on the moon ought to be in the same direction, provided they both were endowed with the same kind of attractive power. But the coefficient of equation (75) is certainly correct in sign, if not in amount; therefore, in order that equation (76) may also be correct, it is necessary that *Jupiter's* influence should be essentially repulsive!

13. We shall now show that the perturbations of the moon by the planets are all of essentially the same character as the similar perturbations produced by the sun. For the disturbing functions due to the sun and planet, which give equations of the forms we have here considered, are

$$\left.\begin{aligned} R &= \tfrac{3}{2}\frac{m'a^2}{a'^3}\left\{ -\tfrac{1}{2}\cos 2(nt - n't) - \tfrac{1}{2} e \cos(3nt - 2n't - \omega) + \tfrac{3}{2} e \cos(nt - 2n't + \omega) \right\} \\ R' &= \tfrac{3}{2}\frac{m''a^2}{a''^3}\, b \left\{ -\tfrac{1}{2}\cos 2(nt - n''t) - \tfrac{1}{2} e \cos(3nt - 2n''t - \omega) + \tfrac{3}{2} e \cos(nt - 2n''t + \omega) \right\} \end{aligned}\right\} \tag{77}$$

in which the masses and distances of the sun and planet are denoted by letters with one accent and two accents respectively; and b denotes the non-periodic term in the development of the inverse fifth power of the planet's distance from the earth. Now the character of the perturbations depends alone upon the variable terms of these forces, while the amount depends upon the coefficients. In the case of the sun and planets, the values of the mean motions n' and n'' are very small in comparison with n, the mean motion of the moon. Now the substitution of these forces in the formulas for the perturbations, will give the same sign to the different terms for all values of n' and n'' which are less than $\frac{1}{3}n$. To illustrate we will take three cases involving as many different values of n', n'', etc. We will suppose that the force R' above corresponds to *Jupiter*, and that we have for *Neptune*

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$$R'' = \frac{3}{2}\frac{m'''a^2}{a'''^3}\,b'\left\{-\tfrac{1}{2}\cos 2(nt-n'''t) - \tfrac{1}{2}\,e\cos(3nt-2n'''t-\omega) + \tfrac{3}{2}\,e\cos(nt-2n'''t+\omega)\right\} \tag{78}$$

Then we shall have, for the *Sun*, *Jupiter* and *Neptune*, respectively,

$$n' = 0.07480133n, \qquad n'' = 0.006306087n, \qquad n''' = 0.0004544718n, \tag{79}$$

And if we denote the perturbations in longitude by δv, $\delta_1 v$, $\delta_2 v$, we shall get

$$\delta v = \frac{3}{2}\frac{m'a^3}{\mu a'^3}\left\{1.291910\sin 2(nt-n't) + e\,(1.846288)\sin(3nt-2n't-\omega) + e\,(45.04373)\sin(nt-2n't+\omega)\right\} \tag{80}$$

$$\delta_1 v = \frac{3}{2}\frac{m''a^3}{\mu a''^3}\,b\left\{0.9376837\sin 2(nt-n''t) + e\,(1.446741)\sin(3nt-2n''t-\omega) + e\,(405.7015)\sin(nt-2n''t+\omega)\right\} \tag{81}$$

$$\delta_2 v = \frac{3}{2}\frac{m'''a^3}{\mu a'''^3}\,b'\left\{0.9181590\sin 2(nt-n'''t) + e\,(1.307550)\sin(3nt-2n''t-\omega) + e\,(5509.801)\sin(nt-2n'''t+\omega)\right\} \tag{82}$$

These equations are all correct to terms of the same order, and the effect of the different mean motions is seen in the coefficients of the different terms. From this we see that the coefficients of the first two terms vary slowly, while the last, or evection term, increases with great rapidity as the mean motion diminishes. There is, however, no change of sign in the coefficients, which confirms what was already evident from the general considerations above stated.

If we reduce these equations to numbers, observing that $b = 1.25953$ and $b' = 1.0069524$, we shall get for the perturbations:

$$\delta v = 2112''\sin 2(nt-n't) + 175''.5\sin(3nt-2n't-\omega) + 4281''\sin(nt-2n't+\omega) \tag{83}$$

$$\delta_1 v = 0''.0140\sin 2(nt-n''t) + 0''.0012\sin(3nt-2n''t-\omega) + 0''.3319\sin(nt-2n''t+\omega) \tag{84}$$

$$\delta_2 v = 0''.00000317\sin 2(nt-n'''t) + 0.0000002\sin(3nt-2n'''t-\omega) + 0''.0010\sin(nt-2n'''t+\omega) \tag{85}$$

These three equations represent, to the same order of approximation, the largest inequalities arising from the attractions of the sun, of *Jupiter* and of *Neptune;* and of those due to planetary action, the *evection* arising from the attraction of *Jupiter* is the only one that has a sensible value.

17. It is therefore manifestly useless to seek for an explanation of the empirical equation discovered by Prof. NEWCOMB in the action of the planets upon the moon. In fact, the explanation of that equation which is given in No. 149 of this Journal, namely, that it is simply the correction of the adopted value of the inequality in longitude due to the oblateness of the earth, in order to reduce it to its true value, is so obviously correct that no further explanation seems necessary; at least until it has been carefully shown that the explanation there given is inadequate for the purpose.

Cleveland, 1887 *June* 7.

ON THE NEW ALGOL-TYPE VARIABLE, *Y CYGNI* 7488

$20^h\ 46^m\ 16^s.1$, $+34°\ 6'\ 57''$ (1855.0)

BY EDWIN F. SAWYER.

My early attention having been called to this star, by Mr. CHANDLER, observations were begun on the evening of December 11, 1886. The star was first detected near minimum on December 21 at $5^h\ 45^m$, Camb. M.T. Since that date, owing to the star's near approach to the sunset horizon, and to other causes, only a few observations have been obtained.

The following table gives the light of the variable at each observation deduced from a preliminary light-scale, formed from the few observations secured:

	Camb. M.T. h m	Light		Camb. M.T. h m	Light
1886 Dec. 11	7 15	9.5	1886 Dec. 27	5.45	3.1
14	6 15	10.0	27	7.45	5.1
16	6 15	10.0	27	8.30	6.4
17	6 30	10.5	27	8.55	8.3
20	5 45	10.0	28	5.45	10.0*
21	5 45	4.3	1887 Jan. 2	6.15	3.6*
23	5 45	10.0:	11	6.05	4.9:
25	6 45	10.0			

Cambridgeport, 1887 *May* 20.

The partially observed increase of light on December 27 fully confirms the interesting character of the light-variations as announced by the discoverer. Although the observations are insufficient to establish precisely the times of minima on the several evenings, when the star was seen below its normal brightness, they afford a general confirmation of the elements given on pp. 48 and 56 of this Journal, as is clearly shown by the following comparison of the latter with the time of the observation on each of the dates in question.

E	Computed Minimum h m	Time of Observation h m
4	1886 Dec. 21 6 3	Dec. 21 5 45
6	27 5 55	27 5 45
8	1887 Jan. 2 5 47	Jan. 2 6 15
11	11 5 35	11 6 5

The observations furnish no evidence of a further subdivision of the period.

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CORDOBA OBSERVATIONS OF COMET 1886 VII. (*FINLAY*)

The accompanying observations were made with the great equatorial and filar-micrometer, using a power of 60, during the first hour of each night before beginning the regular DM. work. The object was a good one for observing, in the main, and I only discontinued the series because it had passed well beyond our hemisphere. Upon the nights of November 4 and December 8, respectively, the comet passed, nearly centrally, $11\frac{1}{2}^{M}$ and 8^{M} stars without apparently diminishing their light. The comparison-star used upon the night of January 16, no. 49 — WB. I. 9 — needs a correction of —10ˢ in the original catalogue.

JOHN M. THOME.

1886 Cord. M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	
d h m s			m s	′ ″	h m s	° ′ ″			
Oct. 14 7 59 50.0	1	4	+3 10.25	— 5 40.8	17 52 29.26	—26 39 14.8	9.666	n0.336	
16 8 0 15.6	2	7	+1 33.74	+11 48.7	17 58 58.08	26 39 12.0	9.668	n0.341	
18 7 51 37.6	3	10	+0 37.10	—12 53.4	18 5 37.79	26 37 57.9	9.658	n0.323	
21 8 18 18.7	4	9	+0 44.67	— 5 47.9	18 16 1.45	26 33 47.1	9.702	n0.414	
22 7 46 37.8	5	8	—1 9.79	+10 6.4	18 19 29.27	26 31 48.4	9.654	n0.317	
23 8 1 29.4	6	7	+1 14.04	+ 9 38.5	18 23 6.76	26 29 22.3	9.674	n0.355	
24 8 5 19.0	7	5	—2 59.34	— 3 48.9	18 26 45.93	26 26 27.4	9.678	n0.366	
25 7 46 47.9	7	10	+0 38.60	— 0 44.0	18 30 23.85	26 23 22.6	9.655	n0.323	
27 7 57 36.2	8	8	+1 15 51	+ 3 46.1	18 37 55.42	26 15 52.3	9.669	n0.353	
29 9 3 26.4	9	7	+1 37.93	+ 2 25.0	18 45 47.83	26 6 22.5	9.729	n0.496	
30 8 30 15.7	10	5	—4 12.46	— 9 9.2	18 49 37.05	26 1 6.2	9.704	n0.431	☄ faint in clouds
Nov. 1 8 25 42.6	11	4	+2 9.70	+ 1 31.3	18 57 33.87	25 49 19.9	9.699	n0.428	
8 8 21 5.0	12	6	—2 19.83	+ 6 47.1	19 26 48.22	24 51 6.6	9.689	n0.424	
13 8 37 48.1	13	6	—2 51.93	+ 6 37.9	19 48 58.72	23 52 0.2	9.699	n0.465	
14 8 47 2.5	14	8	+1 19.10	+ 0 12.6	19 53 33.47	23 38 17.0	9.706	n0.483	
15 8 4 49.9	15	4	+1 18.87	— 8 11.4	19 57 58.13	23 24 30.0	9.661	n0.408	high wind, tel. shaken
16 8 3 33.9	16	7	+0 31.04	— 8 5.3	20 2 36.92	23 9 15.4	9.658	n0.409	
12 3.7	17	6	+0 2.28	+ 2 47.1	20 2 38.18	23 9 14.3	9.669	n0.424	
17 8 15 51.0	18	8	—1 8.82	+ 2 37.7	20 7	22 53	9.671	n0.434	
18 8 8 14.9	19	9	—0 32.84	— 8 26.4	20 11 58.48	22 37 7.2	9.661	n0.439	
19 8 7 53.0	20	7	+1 14.00	— 1 10.0	20 16 40.83	22 20 1.7	9.658	n0.426	
23 8 13 0.0	21	7	+0 56.34	+ 8 21.3	20 35 54.19	21 4 21.6	9.657	n0.448	
24 8 8 41.6	22	8	+0 54.98	— 0 8.5	20 40	20 44	9.649	n0.445	
25 7 59 35.4	23	8	+0 10.09	— 6 23.8	20 45	20 22	9.635	n0.436	
26 8 58 24.4	24	7	+0 13.02	+ 5 49.6	20 50 46.62	19 59 19.9	9.696	n0.523	
27 9 2 3.9	25	7	—0 33.36	+ 5 14.0	20 55 44.72	19 36 18.2	9 696	n0.529	
28 8 10 36.4	26	5	—1 51.88	— 2 31.4	21 0 33.39	19 13 26.1	9.642	n0.465	
23 12.4	27	7	—0 5.79	— 4 7.3	21 0	19 13	9.658	n0.481	
30 8 17 44.6	28	7	—0 59.03	+ 3 36.6	21 10 36.43	18 23 53.6	9.647	n0.482	
Dec. 1 8 15 12.3	29	5	+3 44.04	— 1 59.4	21 15 38.73	17 58 9.0	9.641	n0.484	
3 8 44 28.9	30	7	—2 30.21	— 2 10.0	21 25 53.48	17 3 38.1	9.669	n0.523	
7 8 24 39.2	31	5	—2 14.56	— 1 11.6	21 45	15 7	9.638	n0.535	
8 8 8 55.8	32	6	+1 25.10	— 3 48.0	21 51 23.80	14 38 1.7	9.612	n0.513	☄ very faint
9 8 7 23.4	33	6	+1 9.85	— 6 0.8	21 56 32.	14 7	9.608	n0.519	☄ v. ft. and ill defined
27 8.2	34	5	+3 6.02	— 8 18.6	21 56 36.56	14 6 34.7	9.636	n0.535	
12 8 38 32.3	35	7	+0 39.46	— 0 24.6	22 12 7.	12 29	9.642	n0.558	
14 8 51 32.4	36	6	—2 6.70	— 6 22.5	22 22 32.13	11 21 46.6	9.652	n0.576	
15 8 35 53.2	37	5	—3 1.08	+ 4 37.8	22 27 38.82	10 47 53.4	9.632	n0.571	
35 53.2	38	5	—3 36.46	+ 3 22.7	22 27 38.97	10 47 59.7	9.632	n0.571	
16 8 45 5.5	39	7	—0 39.89	— 2 22.5	22 32 49.80	10 12 56.7	9.641	n0.582	
17 8 20 20.5	40	8	+0 52.24	+ 6 25.9	22 37 55.11	9 37 18.6	9.606	n0.574	
20 8 22 8.2	41	7	—2 7.50	—10 53.1	22 53 22.71	7 51 0.2	9.601	n0.591	
28 8 28 17.0	42	8	+0 26.51	— 9 33.2	23 33 59.93	2 56 11.9	9.593	n0.637	
29 9 8 48.4	43	6	—2 24.15	—10 13.3	23 39 9.87	2 18 25.2	9.654	n0.642	☄ very indistinct
1887 31 8 42 41.5	44	3	—2 1.40	+ 2 44.0	23 48 59.95	— 1 5 45.6	9.609	n0.653	☄ barely visible
Jan. 11 8 48 29.8	45	6	+1 18.93	— 7 27.8	0 41 33.95	+ 5 20 37.3	9.606	n0.698	
13 8 26 25.36	46	5	—0 9.64	+ 3 16.2	0 50 27.	6 25	9.570	n0.710	
14 8 31 37.00	47	5	—1 46.22	+ 3 46.3	0 55 10.30	6 57 16.1	9.578	n0.713	
15 8 29 41.31	48	5	+3 24.80	+ 8 43.6	0 59 38.52	7 28 29.7	9.575	n0.717	
16 8 29 50.89	49	7	+0 36.98	— 1 13.8	1 4 5.62	7 59 18.0	9.571	n0.721	
17 8 22 5.78	50	6	+0 41.20	+ 7 5.9	1 8 28.27	8 29 30.3	9.560	n0.726	
18 8 19 21.7	51	8	—1 36.15	+ 3 23.8	1 12 51.27	8 59 12.6	9.564	n0.728	
20 8 28 17.8	52	7	+1 30.14	+ 8 16.7	1 21 30.70	9 57 18.5	9.571	n0.733	☄ very faint in clouds
24 8 13 58.8	53	10	—0 19.45	— 8 45.0	1 38 21.16	11 46 13.6	9.545	n0.750	
27 8 30 2.7	54	6	+1 58.10	— 9 23.5	1 50 41.05	+13 2 38.9	9.576	n0.751	☄ very faint

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Adopted Mean Places for 1886.0 of Comparison-Stars.

*	Mag.	α	Red. to app. place	δ	Red. to app. place	Authority	
		h m s	s	° ′ ″	″		
1	7¼	17 49 17.32	+1.69	−26 45 2.1	+ 6.5	C. Z.C. 3285	
2	8	17 57 22.64	1.70	26 51 7.6	6.9	C. Z.C. 3839	
3	8½	18 4 58.99	1.70	26 25 11.8	7.3	C. Z.C. 291	
4	8¼	15 15.07	1.71	28 6.9	7.7	A. G.C. 25024	
5	6¾	20 37.34	1.72	42 2.6	7.8	A. G.C. 25160	
6	7	21 51.02	1.70	39 8.6	7.8	A. G.C. 25197	
7	8½	29 43.56	1.71	22 46.7	8.2	A. G.C. 25396	
8	9	36 38.23	1.68	19 46.9	8.5	C. Z.C. 2066	
9	9¼	44 8.22	1.68	26 8 56.4	8.9	C. Z.C. 2438	
10	9½	53 47.81	1.70	25 52 6.3	9.3	C. Z.C. 2860	
11	8¼	18 55 22.48	1.69	25 51 0.6	9.4	A. G.C. 26048	
12	5¾	19 29 6.36	1.69	24 58 4.1	10.4	A. G.C. 26827	
13	9¼	51 48.95	1.70	23 58 49.4	11.3	C. Z.C. 2102	
14	8¼	52 12.66	1.71	38 41.1	11.4	A. G.C. 27343	crimson
15	8½	19 56 42.56	1.70	16 26.2	11.6	A. G.C. 27457	
16	9	20 2 4.17	1.71	1 21.9	11.8	Oe. A. 20264	
17	9	2 34.18	1.72	23 12 13.4	12.0	C. Z.C. 72	
18	9.5	8 27.	1.	22 56			
19	9	12 29.59	1.73	28 52.8	12.0	Oe. A. 20389	
20	8	15 25.11	1.72	22 19 3.8	12.1	A. G.C. 27893	
21	9	34 56.12	1.73	21 12 55.5	12.6	Oe. A. 20744	
22	9½	39 50.		20 44			
23	9¼	54 23.		16			
24	10	50 31.85	1.75	20 5 22.6	13.1	A. G.C. 28711	
25	7¼	20 56 16.31	1.77	19 41 45.5	13.3	Y. 9198	
26	8	21 2 23.49	1.78	11 8.2	13.5	Oe. A. 21151	
27	8	0 41.		19 9			
28	5.5	11 33.66	1.80	18 27 43.9	13.7	A. G.C. 29215	
29	7	11 52.90	1.79	17 56 23.4	13.8	A. G.C. 29220	
30	9	28 21.86	1.83	17 1 42.1	14.0	Ll. 41941	
31	9	47 9.		15 6 14.			
32	8	49 56.86	1.84	14 34 28.1	14.4	½(Ll. + W.B.)	
33	9½	55 20.		14 1			
34	9	21 53 28.69	1.85	13 58 30.7	14.6	W.B. 1210	
35	9½	22 11		12 30			
36	5	24 36.86	1.97	11 15 39.2	15.1	A. G.C. 30696	
37	8½	30 37.91	1.99	10 52 46.3	15.1	Y. 9924	
38	8½	31 13.44	1.99	51 37.5	15.1	Y. 9932	
39	9	33 27.69	2.00	10 10 49.4	15.2	W.B. 672	
40	8	37 0.87	2.00	9 43 59.7	15.2	W.B. 752	
41	6½	22 55 28.16	2.05	7 40 22.4	15.3	A. G.C. 31293	
42	9	23 33 31.20	2.22	2 46 54.3	15.6	Ll. 46334	
43	8½	41 31.76	2.26	2 8 27.4	15.5	Y. 10482	
44	9	23 50 59.06	+2.29	− 1 8 44.9	+15.3	W.B. 1008	

Adopted Mean Places for 1887.0.

*	Mag.	α	Red. to app. place	δ	Red. to app. place	Authority	
45	8½	0 40 15.58	−0.56	+ 5 28 10.1	− 5.0	W.B. 668	
46	9¾	50		6 22			
47	8½	56 57.02	0.50	6 53 35.1	5.3	½(W.B. + Ll.)	
48	7	0 56 14.23	0.51	7 19 51.3	5.3	Y. 527	
49	9	1 3 29.12	0.48	8 0 37.1	5.3	W.B. 9	corr. to W.B. −10″
50	8¼	7 47.54	0.47	22 29.8	5.4	W.B. 74	
51	8	14 27.86	0.44	8 55 54.2	5.4	W.B. 193	
52	8	20 0.98	0.42	9 49 7.2	5.4	Y. 681	
53	9	38 40.95	0.34	11 55 4.0	5.4	W.B. 677	
54	8	1 48 43.28	−0.33	+13 12 7.8	− 5.4	Ll. 31514	

Cordoba, 1887 *June* 12.

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OBSERVATIONS OF COMET 1887 *e* (*Barnard, May 12*)

MADE AT THE HARVARD COLLEGE OBSERVATORY

By O. C. WENDELL, Assistant.

(Communicated by Prof. Edward C. Pickering, Director.)

1887 Greenwich M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
	h m s			m s	′ ″	h m s	° ′ ″		
June 7 14 29 42	1	5	—1 9.15	— 4 49.8	16 0 13.09	—12 31 12.7	n9.131	0.854
8 14 14 42	2	5	+0 50.99	— 7 24.4	16 2 23.47	—11 44 13.5	n9.202	0.848
13 16 41 58	3	5	+1 48.22	+11 21.1	16 13 41.93	— 7 48 48.8	n9.136	0.828
14 14 41 53	4	5	—1 11.72	—11 41.5	16 15 45.32	— 7 8 9.2	n8.944	0.825
15 14 27 31	5	5	+1 31.93	+11 1.8	16 17 59.52	— 6 24 42.0	n9.036	0.821
25 15 28 32	6	5	+2 54.90	— 5 19.7	16 40 39.59	+ 0 3 26.3	+8.622	0.772

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	16 1 20.15	+2.09	—12 26 27.2	+4.3	Ll. 29331
2	16 1 30.40	+2.08	—11 36 53.2	+4.1	Weisse 15h.1138
3	16 11 51.67	+2.04	— 8 0 12.7	+2.8	Weisse 16h.184
4	16 16 55.00	+2.04	— 6 56 30.7	+3.0	Ll. 29798
5	16 16 25.54	+2.05	— 6 35 47.1	+3.3	Weisse 16h.272
6	16 37 42.62	+2.07	+ 0 8 40.1	+5.9	BB. VI. +0°.3571

On June 13, and subsequently, an incipient tail was noticed, about 2′ long.

ON A NEW VARIABLE OF THE ALGOL-TYPE

R Can Maj. 2610.

7h 13m 49s, —16° 9′.7 (1875.0)

By EDWIN F. SAWYER.

I beg to announce that I have discovered the star 155 (U.A.) *Canis Majoris* to be a variable of the *Algol*-type.

On the evening of March 26, while observing sequences in the constellation *Canis Major*, in connection with my revision of the southern star magnitudes, the unusual faintness of this star attracted my notice by the marked alteration in the aspect of the rather conspicuous group in the opera-glass, formed by this star with nos. 144, 156, 165 and 169 (U.A.) *Canis Majoris*. Only two evenings previous it had appeared of the usual brightness. Careful comparison with the neighboring stars showed that no. 155 was about 6M.8. My two previous observations of the star had made it 6M.3 and 6M.4, while in the *Uranometria Argentina* it is 6M.2. The evening being remarkably clear, there could be no mistake in the observation.

The next opportunity of observing the star occurred on March 29, when it was found at its normal brightness. Other observations at normal brightness followed until April 11 (an interval of sixteen days), when the star was again observed near minimum, and the interesting character of the variations established. Two other observations, at intervals of eight days, were secured when the star was near minimum, including a good observation of the increase of light on April 19 and an apparent decrease on the following evening, when, however, the star was low. It will thus be seen that the period is some aliquot part of eight days, and if the last observation is to be depended upon it is 1d 3h±. The star was not again observed in faint light, the observations terminating on May 1, owing to its near approach to the sunset horizon. It is uncertain, as yet, whether the star has been actually observed at minimum; the observed fluctuation in light has however amounted to about half a magnitude.

As the star will not be visible here for several months, I have thought it best to publish the meager facts so far obtained, so that observers more favorably located may have an opportunity of obtaining earlier observations from which to determine the elements. The comparison-stars, together with my provisional light-scale used, are as follows:

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		Eq. 1875.0 α	δ	Magnitude U.A.	Sawyer	Light
		h m s	° ′			
a =	156 (U.A.) *Canis Majoris*	7 15 15	—14 7.7	6.2	6.25	16.1
b =	169 " " "	7 19 24	—13 30.4	6.4	6.45	14.0
c =	152 " " "	7 13 33	—19 3.1	6.6	6.65	10.0
d =	168 " " "	7 19 20	—18 46.1	6.8	6.70	9.7
e =	153 " " "	7 13 43	—17 17.8	7.0	6.95	5.0

The following table gives the light of the variable at each observation. The letter n signifies that the star was observed at its normal or maximum brightness, which is about 14.5 or 14.8 of the light-scale.

Observations.

Cambridge M.T.	h	Light	Cambridge M.T.	h	Light
1887 Mar. 24	7.45	n:	1887 Apr. 10	7.45	n:
26	10.00	9.3	10	9.30	n:
29	8.15	14.3*	11	8.15	10.0::
30	7.45	14.1*	11	9.00	n::
Apr. 6	7.45	14.8*	12	7.35	n:
7	7.45	14.8*	14	7.45	n
9	7.45	n*	17	7.45	n

Cambridge M.T.	h	Light	Cambridge M.T.	h	Light
1887 Apr. 19	7.40	10.5:	1887 Apr. 21	8.15	n
19	7.55	10.5	22	8.15	n
19	8.10	11.5	22	9.00	n:
19	8.35	13.2	24	8.00	n
19	9.15	14.5:	24	8.45	n:
19	9.45	14.8:	27	7.45	n
20	8.00	14.4	27	8.45	n*
20	9.15	11.8:	May 1	7.55	n*

It is rather a curious fact that the star is only contained in the *Uranometria Argentina*, although of the magnitude 6.2. As it is the first certainly variable star discovered in *Canis Major* it will probably be known as *R Canis Majoris*.

Cambridgeport, 1887 *July* 4.

THE NOMENCLATURE OF DOUBLE STARS.

I frequently have requests for observations of double stars, which I should be glad to make, especially in the case of rapid motion, if the writers would take the pains to give the position of the star. Instead of doing this, they usually make an obscure reference by means of symbols, or the initial letters of astronomers, which require considerable ingenuity and labor to understand. The symbols Σ and $O\Sigma$, used to designate the Struves are well known, and the fundamental work done by them in this branch of astronomy deserves commemoration. But the increase of symbols has already become inconvenient, and must lead to confusion. It would be better, I think, even at the risk of dampening the ardor of discoverers, to omit the introduction of new symbols until the astronomer has found a pretty large number of new double stars.

A. HALL.

Naval Observatory, 1887 *July* 18.

CORRIGENDA.

No. 158, p. 107. Equation (33), the signs of the 5th and 6th terms should be inverted.
p. 108. Equation (34), the signs of the 1st, 3d, 6th, 7th and 10th terms should be inverted.

CONTENTS.

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THE

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IMPROVED ELEMENTS AND EPHEMERIS OF COMET 1887 *e*,

BY S. C. CHANDLER, JR.

The ephemeris below is designed to follow this comet until its disappearance. Probably position-measurements will not be practicable with instruments of moderate size much after the middle of August; but with the more powerful telescopes the comet ought to be followed well into September, perhaps to the end.

For the convenience of computers and others desirous of making comparison with observations, I have continued the ephemeris from the last date of that in No. 157 of the *Journal*, but have based it upon the following improved elements.

$$T = \text{June } 16.65526 \text{ Greenw. M.T.}$$

$$\left.\begin{aligned} \omega &= \;\;15^\circ \;\; 7' \; 30''.3 \\ \Omega &= 245 \;\; 12 \;\; 59\;.3 \\ i &= \;\;17 \;\; 35 \;\; 22\;.1 \end{aligned}\right\} \text{Eq. } 1887.0$$

$$\log q = 0.1445436$$

These elements were computed from the normals for May 14 and May 30, given in No. 157, conjoined with the following, also corrected for parallax and aberration, and referred to the mean equinox 1887.0.

	Obs.	Greenw. M.T.	α	δ
June 8–14	4	June 12.16667	16ʰ 10ᵐ 16ˢ.69	—8° 57′ 40″.7
July 12	4	July 12.65023	17 18 3.59	+6 46 54.9

The representation of the middle places (C—O)

	May 30	June 12
$\Delta\lambda \cos\beta$	—17″.2	—18″.7
$\Delta\beta$	— 2 .3	—12 .5

is not susceptible of improvement by varying the ratio of the distances. Therefore if the places employed are correct, of which I cannot entirely assure myself at the time and place of writing, the orbit will prove to be sensibly elliptical.

CONSTANTS FOR THE EQUATOR, 1887.0

$$x = r\,[9.9830063]\,\sin\,[349^\circ\,16'\,52''.7+v]$$
$$y = r\,[9.9844119]\,\sin\,[254\;\;49\;\;\;1\;.7+v]$$
$$z = r\,[9.5800008]\,\sin\,[303\;\;14\;\;\;9\;.6+v]$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1887	App. α	Hourly Motion	App. δ	Hourly Motion	log r	log Δ	Light
	h m s	s	° ′ ″	″			
July 9.5	17 11 20.26	+5.386	+5 56 1.5	+44.48	0.156506	9.702606	1.01
11.5	15 37.59	5.336	6 29 33.4	39.39			
13.5	19 52.55	5.287	6 59 7.3	34.50	0.160867	9.723873	0.90
15.5	24 5.11	5.238	7 24 54.1	29.95			
17.5	28 15.37	5.191	7 47 6.2	25.59	0.165804	9.745885	0.79
19.5	32 23.40	5.145	8 5 54.3	21.47			
21.5	36 29.28	5.101	8 21 31.2	17.62	0.171270	9.768426	0.70
23.5	40 33.11	5.059	8 34 9.3	14.02			
25.5	44 34.96	5.019	8 44 1.1	10.69	0.177216	9.791322	0.61
27.5	48 34.96	4.981	8 51 19.2	7.61			
29.5	52 33.11	4.942	8 56 15.0	4.76	0.183591	9.814430	0.53
31.5	17 56 29.42	4.905	8 59 0.5	+ 2.17			
Aug. 2.5	18 0 23.94	4.867	8 59 46.5	— 0.22	0.190346	9.837641	0.46
4.5	4 16.70	4.832	8 58 43.1	2.39			
6.5	8 7.79	4.797	8 56 0.1	4.37	0.197431	9.860881	0.40
8.5	11 57.25	4.765	8 51 46.6	6.17			
10.5	15 45.20	4.734	8 46 11.0	7.78	0.204803	9.884102	0.35
12.5	19 31.75	4.706	8 39 22.1	9.23			
14.5	23 16.97	4.680	8 31 27.7	10.52	0.212414	9.907261	0.30
16.5	27 1.03	4.657	8 22 34.9	11.65			
18.5	30 44.01	4.636	8 12 51.8	12.62	0.220226	9.930827	0.26
20.5	34 26.04	4.616	8 2 25.2	13.46			
22.5	38 7.16	+4.598	+7 51 21.9	—14.16	0.228199	9.953259	0.23

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1887	App α	Hourly Motion	App. δ	Hourly Motion	log r	log Δ	Light
	h m s	s	° ′ ″	″			
Aug. 24.5	18 41 47.46	+4.581	+7 39 48.2	—14.73			
26.5	45 26.95	4.565	7 27 49.9	15.18	0.236301	9.976022	0.20
28.5	49 5.67	4.549	7 15 32.4	15.53			
30.5	52 43.61	4.532	7 3 0.7	15.78	0.244498	9.998585	0.17
Sept. 1.5	56 20.75	4.516	6 50 19.4	15.93			
3.5	18 59 57.13	4.500	6 37 32.6	16.01	0.252763	0.020923	0.15
5.5	19 3 32.76	4.485	6 24 43.9	16.01			
7.5	7 7.66	4.470	6 11 56.7	15.97	0.261070	0.043022	0.13
9.5	10 41.88	4.456	5 59 13.9	15.82			
11.5	14 15.46	4.443	5 46 38.6	15.64	0.269398	0.064868	0.11
13.5	17 28.45	4.431	5 34 13.6	15.40			
15.5	21 20.87	4.421	5 22 1.4	15.10	0.277726	0.086446	0.10
17.5	24 52.80	4.410	5 10 4.6	14.76			
19.5	28 24.23	4.400	4 58 25.3	14.37	0.286037	0.107734	0.09
21.5	31 55.20	4.390	4 47 6.0	13.93			
23.5	35 25.66	4.379	4 36 8.3	13.47	0.294316	0.128710	0.08
25.5	38 55.62	4.369	4 25 33.6	12.97			
27.5	42 25.07	+4.358	+4 15 24.1	—12.43	0.302552	0.149356	0.07

Gloucester, Mass., 1887 *July* 28

Subsequent to the preparation of the foregoing ephemeris a computation of elliptic elements was made with the normal places of May 14, June 12, and July 12, as follows:

ELEMENTS.

$$
\begin{aligned}
T &= \text{June } 16.66108 \text{ Greenw. M.T.}\\
\left.\begin{aligned}
\omega &= 15^\circ\ 8'\ 3.7''\\
\Omega &= 245^\circ\ 13'\ 16.8''\\
i &= 17^\circ\ 32'\ 53.4''
\end{aligned}\right\}&\ 1887.0\\
\log q &= 0.1441634\\
\log a &= 2.5009248\\
e &= 0.9956014
\end{aligned}
$$

The corresponding constants for the equator (1887.0) are:—

$$
\begin{aligned}
x &= r\,[9.9830852]\ \sin\,[349^\circ\ 18'\ \ 2''.6+v]\\
y &= r\,[9.9843660]\ \sin\,[254^\circ\ 50'\ 26''.1+v]\\
z &= r\,[9.5797903]\ \sin\,[303^\circ\ \ 9'\ 11''.7+v]
\end{aligned}
$$

The corrections to the previous ephemeris necessary to represent these later elements are given in the following table:

	s	′		s	″		s	″
July 9.5	—0.23	+ 4.3	Aug. 6.5	+1.56	—35.7	Sept. 3.5	+3.81	—71.4
11.5	—0.12	+ 1.6	8.5	1.70	38.6	5.5	3.98	73.4
13.5	—0.01	— 1.0	10.5	1.84	41.5	7.5	4.16	75.3
15.5	+0.12	3.7	12.5	1.98	44.4	9.5	4.34	77.1
17.5	0.24	6.5	14.5	2.13	47.3	11.5	4.52	78.8
19.5	0.36	9.3	16.5	2.28	50.0	13.5	4.70	80.3
21.5	0.49	12.1	18.5	2.43	52.7	15.5	4.89	81.8
23.5	0.62	14.9	20.5	2.59	55.2	17.5	5.07	83.2
25.5	0.75	17.8	22.5	2.76	57.8	19.5	5.26	84.5
27.5	0.88	20.8	24.5	2.93	60.2	21.5	5.45	85.7
29.5	1.01	23.8	26.5	3.10	62.6	23.5	5.64	86.8
31.5	1.14	26.8	28.5	3.28	64.9	25.5	5.83	87.8
Aug. 2.5	1.28	29.8	30.5	3.46	67.2	27.5	+6.03	—88.8
4.5	+1.42	—32.8	Sept. 1.5	+3.63	—69.3			

The only later observations to which I have access, namely, those of Mr. BARNARD, in another part of the Journal, show a much closer accordance with the ephemeris after applying these corrections. Thus, for July 26 the differences ($O—C$) $\Delta\alpha = +1^s.84$, $\Delta\delta = —31''.3$, are reduced to $+0^s.92$ and $—11''.9$. This confirms the correctness of the normal places, and strengthens the probability of the existence of a real deviation from the parabola.

1887 *August* 21.

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DETERMINATION OF THE COEFFICIENTS OF EXPANSION OF THE GLASS PLATES USED FOR STELLAR PHOTOGRAPHY AT CORDOBA, IN THE YEARS 1872 TO 1876, AND 1880 TO 1883,

BY WILLIAM A. ROGERS.

The following determination of the coefficients of expansion of the glass plates used by Dr. GOULD, in his photographic observations at Cordoba, depends upon comparisons of decimeters, traced upon the two specimens of glass selected, with the following standards of length: — (*a*) the first decimeter of a standard meter upon Baily's metal; (*b*) the first decimeter of a standard meter upon Jessup's steel; (*c*) the first decimeter of a standard meter upon glass, graduated by the writer for the Standards Department of the British Board of Trade. Standard (*a*) is designated R_2; standard (*b*) is designated R_3; standard (*c*) is designated G.

No special pains were taken to make the transfers to the photographic glass very exact, as the object was the determination of the law of expansion, rather than the absolute length of the transfers.

The observations, which are sixty in number, extend from March 17 to July 10, of the current year. By an observation is to be understood a comparison, consisting of eight readings, between the two decimeters upon the photographic glass and the decimeters R_2, R_3 and G.

The values R_2—(1), R_3—(1), and G—(1) represent the differences in length between R_2, R_3, G, and the decimeter upon the glass used between the years 1872 and 1876. The values R_2—(2), R_3—(2), and G—(2) represent the differences in length between R_2, R_3, G and the decimeter upon the glass used during the years 1880 and 1883. These differences are expressed in terms of divisions of the micrometer employed. One division of this micrometer = 0.567μ. The following results of direct comparisons are arranged in the order of temperatures.

Date of Obs.	Temp. °	R_2—(1)	R_3—(1)	G—(1)	R_2—(2)	R_3—(2)	G—(2)
1887 Apr. 1	+15.9 F	+27.3 div.	+61.2 div.	+46.1 div.	+ 5.1 div.	+40.1 div.	+25.0 div.
Mar. 27	17.1	30.0	58.8	45.0	10.6	36.0	21.0
27	17.2	29.6	59.3	46.4	13.6	33.3	21.4
30	18.6	38.0	59.8	50.0	4.7	33.5	16.7
30	18.7	41.1	56.3	46.0	10.9	29.1	15.8
Apr. 1	19.1	35.2	61.1	45.0	10.4	36.3	22.0
Mar. 31	20.8	35.8	66.0	48.2	11.1	41.3	23.5
Apr. 8	22.0	36.1	62.1	48.0	9.2	36.2	21.9
Mar. 24	22.3	38.2	60.9	46.5	17.2	39.9	25.8
24	22.4	34.0	57.8	45.4	15.2	39.0	26.3
24	24.0	35.8	58.5	43.5	15.1	37.8	22.7
Apr. 8	24.2	34.3	66.1	51.0	6.5	38.3	23.2
Mar. 31	24.9	38.9	64.4	49.0	13.0	38.5	25.5
Apr. 18	29.2	41.4	60.7	44.9	18.7	38.0	22.2
6	30.3	39.2	60.9	45.0	18.2	39.9	24.9
13	31.9	48.0	62.8	43.6	27.5	42.3	23.1
Mar. 29	32.5	31.9	55.6	41.8	9.6	33.3	19.5
30	33.0	43.9	64.7	44.5	20.8	41.6	21.4
Apr. 15	33.8	42.8	65.2	49.1	15.6	36.3	22.9
19	34.6	44.5	59.6	43.7	23.5	38.6	22.7
14	36.1	44.5	59.4	46.5	25.0	39.9	27.0
Mar. 30	36.4	49.1	65.7	47.6	24.1	42.3	22.6
Apr. 28	36.8	44.5	63.4	51.1	20.3	39.2	27.2
Mar. 22	36.8	44.6	58.5	43.7	23.7	37.6	22.8
25	37.0	43.2	61.6	43.8	20.5	38.9	21.1
Apr. 7	38.3	44.9	59.1	42.4	24.7	38.9	22.2
Mar. 29	38.6	51.7	66.1	44.0	20.8	35.3	15.9
25	39.0	48.8	65.0	44.0	21.7	38.9	22.0
22	39.2	49.1	66.7	41.7	20.5	38.1	13.1
Apr. 6	39.3	40.5	56.1	46.9	18.1	34.2	24.5
Mar. 29	39.6	48.5	61.7	43.0	24.2	37.4	20.0
22	40.2	41.5	59.8	41.3	26.0	39.3	21.2
27	42.1	51.8	63.4	49.4	23.7	35.3	21.3
21	43.4	52.3	66.9	42.6	26.6	40.8	16.5
17	43.7	42.8	59.1	43.8	19.6	35.7	16.4
17	46.8	54.8	64.2	43.3	28.2	37.6	18.7
Apr. 17	+46.8 F	+58.1 div.	+68.3 div.	+48.3 div.	+38.2 div.	+48.4 div.	+28.4 div.

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Date of Obs.	Temp.	R_2—(1)	R_3—(1)	G—(1)	R_2—(2)	R_3—(2)	G—(2)
1887 Mar. 23	+47.8 F	+40.0 div.	+63.6 div.	+47.8 div.	+14.6 div.	+38.2 div.	+21.4 div.
20	47.8	63.1	72.7	52.7	29.0	38.0	18.6
20	48.0	59.1	65.1	43.8	34.3	41.2	19.9
20	48.6	55.8	67.8	45.2	28.2	40.0	17.6
17	48.9	60.6	69.1	44.6	30.4	38.9	20.4
23	49.9	44.5	59.0	43.6	33.2	37.1	17.8
28	50.7	62.0	63.6	49.2	38.2	39.8	25.2
23	60.3	73.8	74.0	51.7	48.9	49.1	26.8
23	62.1	68.2	61.3	46.0	42.0	35.1	19.6
23	66.2	72.5	68.3	47.1	46.2	42.0	21.8
May 25	72.1	82.0	72.3	46.4	60.6	51.1	25.2
25	72.1	82.9	69.8	52.0	58.0	44.9	27.1
July 10	73.4	75.5	71.1	48.0	54.4	49.5	26.8
10	73.4	77.5	72.7	48.2	57.6	52.8	28.3
9	75.7	80.3	70.5	44.7	62.1	52.3	26.5
9	75.7	80.2	70.4	42.9	62.8	53.0	25.5
8	81.2	92.0	81.2	55.5	64.4	53.6	27.9
8	81.2	83.7	74.1	48.5	63.1	53.5	27.9
8	81.6	89.6	78.6	53.0	62.7	51.7	26.1
8	82.0	89.7	72.3	47.7	64.3	67.8	22.3
8	82.2	87.7	74.5	44.0	63.7	70.5	20.0
8	82.3	87.9	74.2	43.5	72.3	58.6	31.9
8	+82.3 F	+86.4 div.	+74.4 div.	+49.8 div.	+67.2 div.	+55.2 div.	+30.6 div.

The following equations of condition are formed by the substitution of the observed data in the equation

$$\Delta = a + (62^\circ.0 - T)\, b$$

in which

Δ = the observed relations R_2—(1), R_3—(1), etc.

a = the difference in length between the decimeters upon the photographic glass and those upon the standards R_2, R_3, and G.

b = the relative coefficients of expansion between R_2, R_3, and G and the photographic glass, for each degree Fahrenheit.

Each equation results from the mean of ten comparisons. The values of the unknown quantities, a and b, having been obtained from the solution by least squares, the value of a for each equation was obtained by the substitution of the derived value of b. The several values of a, thus computed, are written at the right of the equations, and the agreement of their mean with the value derived from the normal equations furnishes a complete check upon the accuracy of the solution. The agreement *inter se* furnishes a test of the magnitude of the probable errors of observation.

R_2—(1)			$(62^\circ.0-T)$	a at $62^\circ.0$
+34.5 div.	=	a	$+42.59\,b$	+71.6 div.
40.1	=	a	$32.16\,b$	68.1
46.1	=	a	$24.25\,b$	67.2
51.2	=	a	$17.38\,b$	66.3
67.8	=	a	$+\ 1.57\,b$	69.2
+85.5	=	a	$-17.76\,b$	+70.0
				Mean 68.75

NORMAL EQUATIONS.

$$+325.2 = 6\,a + 100.19\,b$$
$$+3354.6 = 100.19\,a + 4056.3\,b$$
$$b = -0.871 \text{ div.} = -0.494\,\mu$$
$$a = +68.75 \text{ div.}$$

R_3—(1)			$(62^\circ.0-T)$	a at $62^\circ.0$
+60.3 div.	=	a	$+42.59\,b$	+70.2 div.
61.8	=	a	$32.16\,b$	69.3
62.3	=	a	$24.25\,b$	68.
64.5	=	a	$17.38\,b$	68.6
67.6	=	a	$+\ 1.57\,b$	68.0
+74.4	=	a	$-17.76\,b$	+70.3
				Mean 69.1

NORMAL EQUATIONS.

$$+390.9 = 6\,a + 100.19\,b$$
$$+5972.1 = 100.19\,a + 4056.3\,b$$
$$b = -0.233 \text{ div.} = -0.132\,\mu$$
$$a = +69.1 \text{ div.}$$

G—(1)			$(62^\circ.0-T)$	a at $62^\circ.0$
+46.7 div.	=	a	$+42.59\,b$	+47.4 div.
45.7	=	a	$32.16\,b$	46.2
45.2	=	a	$24.25\,b$	45.6
45.6	=	a	$17.38\,b$	45.9
47.4	=	a	$+\ 1.57\,b$	47.4
+47.8	=	a	$-17.76\,b$	+47.5
				Mean 46.7

NORMAL EQUATIONS.

$$+278.4 = 6\,a + 100.19\,b$$
$$+4582.9 = 100.19\,a + 4056.3\,b$$
$$b = -0.028 \text{ div.} = -0.016\,\mu$$
$$a = +46.7 \text{ div.}$$

R_2—(2)			$(62^\circ.0-T)$	a at $62^\circ.0$
+10.8 div.	=	a	$+42.59\,b$	+49.2 div.
16.8	=	a	$32.16\,b$	45.8
21.9	=	a	$24.20\,b$	43.7
26.4	=	a	$17.38\,b$	42.1
44.0	=	a	$+\ 1.57\,b$	45.5
+64.0	=	a	$-17.76\,b$	+48.0
				Mean 45.7

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NORMAL EQUATIONS.

$$+183.9 = 6a + 100.19b$$
$$+922.2 = 100.19a + 4056.3b$$
$$b = -0.902 \text{ div.} = -0.511\mu$$
$$a = +45.7 \text{ div.}$$

R_3—(2)			(62°.0—T)	a at 62°.0
+36.5 div.	=	a	+42.59 b	+53.9 div.
38.5	=	a	32.16 b	51.6
38.3	=	a	24.25 b	48.2
39 2	=	a	17.38 b	46.3
42.7	=	a	+ 1.57 b	43.3
+54.9	=	a	—17.76 b	+47.6
			Mean	+48.5

NORMAL EQUATIONS.

$$+250.1 = 6a + 100.19b$$
$$+3494.9 = 100.19a + 4056.3b$$
$$b = -0.286 \text{ div.} = -0.162\mu$$
$$a = +48.5 \text{ div.}$$

G—(2)			(62°.0—T)	a at 62°.0
+21.9 div.	=	a	+42.59 b	+24.9 div.
22.8	=	a	32,16 b	25.1
21.8	=	a	24.25 b	23.5
20.2	=	a	17.38 b	21.4
22.8	=	a	+ 1.57 b	22.9
+26.7	=	a	—17.76 b	+25.4
			Mean	+23.9

NORMAL EQUATIONS.

$$+136.2 = 6a + 100.19b$$
$$+2170.0 = 100.19a + 4056.3b$$
$$b = -0.070 \text{ div.} = -0.041\mu$$
$$a = +23.9 \text{ div.}$$

The following values have been adopted * for the absolute coefficients of expansion of R_2, R_3, and G:

Coefficient of R_2 for one decimeter $= 0.954\,\mu$
" " R_3 " " $= 0.570\,\mu$
" " G " " $= 0.447\,\mu$

We have therefore:

	Coefficient of (1)	Coefficient of (2)
From R_2	$= 0.460\,\mu$	$0.443\,\mu$
R_3	$= 0.438\,\mu$	$0.408\,\mu$
G	$= 0.431\,\mu$	$0.406\,\mu$

At the time when these comparisons were made, the writer was engaged in a long series of observations, which have resulted in the establishment of the invariability of the coefficients of expansion of Baily's metal, of Jessup's steel and of Chance & Son's glass, between the limits of —3° and +93° Fahrenheit. It was found to be essential that all the observations of this series should be made at the critical point of time in the day, when the bars of metal and the surrounding air were of the same temperature. This critical point of quiescence was found to occur on clear days about half an hour after sunrise, and on cloudy days at a considerably later time.

On account of the exigencies of this extended investigation, it was found to be necessary to depart from the plan of obtaining an equal number of comparisons at equal distances in time from the critical point of no variation in temperature, in the series of observations here recorded. One-third weight will, therefore, be given to the value of the coefficients derived from comparisons with R_2.

We have, finally, for the absolute coefficients of the specimens of photographic glass, for each degree Fahrenheit, and for the length of one decimeter:

Coefficient of (1) $= 0.438\,\mu$
" " (2) $= 0.412\,\mu$.

* See *Proceedings of the American Academy of Arts and Sciences* for 1882, page 385, and *Proceedings of the American Microscopical Society* for 1885, page 157.

Colby University, Waterville, Me., 1877 *July* 14.

VARIABILITY OF DM. 3°,766,

1805

BY LEWIS BOSS.

The star DM. 3°,766 appears to be variable. Its magnitude is given as $9^M.2$ in the DM., and it was twice observed by ARGELANDER with the Bonn meridian-circle (*Bonner Beob.*, Bd. VI.), where its magnitude is also given as 9.2. It was looked for in vain with the Albany meridian-circle during the winter months of 1880–1, and in 1881–2, with especial care, when DM. 3°,764 ($9^M.5$) was easily observed. With 13-inch equatorial of this observatory, a search was made August 13.7 of this year, and a star, estimated to be of the magnitude 11.5, was found, which had the following position by a rough comparison with DM. 3°,764 (Albany A. G. Zone):

$$1875.0: \ \alpha = 4^h\,59^m\,28^s.27\,; \ \delta = 3°\,55'\,48''.0$$

This agrees with the Bonn position of DM. 3°,766 within $0^s.45$ and $3''.2$ respectively, and leaves no doubt of the identification. It appears, therefore, that this star belongs either to the class of "temporaries," or that it is a variable of long period.

Dudley Observatory, 1887 *August* 15.

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RING-MICROMETER OBSERVATIONS OF COMET 1887 *e* (*Barnard, May 12*)

MADE AT THE VANDERBILT UNIVERSITY OBSERVATORY

By E. E. BARNARD.

1887 Nashville M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ
d h m s			m s	′ ″	h m s	° ′ ″
July 8 10 36 53	1	4	—4 57.05	+ 2 13.9		
9 9 17 45	2	3	+3 24.01	+ 1 22.0		
9 9 57 21	3	1	+4 19.31	—12 36.8	17 11 40.31	+5 58 34.7
9 10 14 18	4*	4	—1 41.24	—13 41.1	17 11 41.16	5 58 35.4
9 10 19 57	5	3	+0 19.15	+ 0 16.6	17 11 42.80	5 58 49.5
11 12 00 22	6	6 , 7	+0 48.24	— 0 5.4	17 16 8.40	6 33 3.0
13 10 21 38	7	6	—7 52.18	—14 27.5	17 20 14.68	7 1 12.9
13 10 21 38	8	6	—5 2.23	—18 2.0		
14 10 31 31	9	10 , 11	—5 44.89	— 1 7.2	17 22 21.96	7 14 33.4
15 9 59 14	10	8	+3 31.43	—15 26.3	17 24 25.21	7 26 26.2
16 11 0 47	11	14 , 12	+0 18.20	∓ 0 42.0		
19 9 41 39	12	6	—1 49.32	+14 43.2	17 32 42.39	8 6 44.2
20 10 6 15	13	4	—1 40.67	— 1 48.1		
26 13 3 18	14	8 , 7	+1 28.90	+14 26.5	17 47 10.15	+8 48 20.1
Aug. 10 9 36 55	15	9 , 6	+0 26.40	+ 9 14.7		
11 9 37 44	15	8 , 10	+2 18.82	+ 6 51.5		

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	17 14 25	+2.13	+5 43	+ 9.4	8^M; equatorial
2	17 8 11	2.08	5 56	9.1	8^M; approximate
3	17 7 18.9	2.10	6 11 2.1	9.4	Grant (Glasgow Catalogue) 4241
4	17 13 21.3	2.12	6 12 16.5	9.5	Grant 4259
5	17 11 21.5	2.12	5 58 23.3	9.6	3 ring-micrometer comp.s with Grant 4259
6	17 15 18.0	2.11	6 32 58.5	9.9	Grant 4271
7	17 28 4.7	2.13	7 15 29.8	10.6	Grant 4327
8	17 30 54	2.13	7 19	10.7	Approximate
9	17 28 4.7	2.12	7 15 29.8	10.8	Grant 4327. Same star as no. 7
10	17 20 51.7	2.11	7 41 41.6	10.9	Yarnall 7247
11	17 26 14	2.11	7 39	11.2	9^M; approximate middle of three 9^M stars
12	17 34 29.6	2.14	7 51 49.2	11.8	Grant 4351
13	17 36 24	2.15	8 17	12.0	$8\frac{1}{2}^M$; approximate
14	17 45 39.1	2.12	8 33 40.5	13.1	Grant 4405
15	18 15 39	+2.13	+8 35	+14.4	8^M; equatorial

*The tabulated annual precession in R.A. for this star in the Glasgow Catalogue is 1^s too great.

The comet has been difficult to observe. When possible, the small star-like nucleus (latterly in n. part of the nebulosity) was observed, otherwise the brightest part. The comet has presented a faint, fan-shaped tail in these observations.

Vanderbilt University Observatory, 1887 *August* 12.

THE PERSEIDS, 1887.

The following observations of these meteors were made by my sons from the roof of my house in Georgetown:

August 10th. The sky partly cloudy; watched from 8^h 30^m until 9^h 30^m, and counted eight meteors.

Angelo Hall and Percival Hall.

August 11th. Some clouds, and rain later in the night: watched from 8^h 30^m until 9^h 30^m, and counted nine meteors. The same observers as on the 10th.

August 12th. Partly cloudy; watched from 8^h 10^m until 9^h 45^m, seven meteors. Angelo Hall.

August 13th. A fine, clear night; watched from 8^h 10^m until 10^h, and counted twelve meteors.

Angelo Hall.

About half of these meteors were bright, and left trails of light behind them. One that appeared on August 13th, at 8^h 50^m, exploded in a flame as bright as *Venus*. Most of the meteors moved slowly.

It was cloudy on August 14th and 15th.

Washington, 1887 *August* 16.

A. Hall.

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THE VARIABLE STAR ζ *GEMINORUM*,

BY WM. MAXWELL REED.

The following times of maximum and minimum have been determined from a series of thirty-seven observations during the current year. They are, to a certain extent, provisional, since a longer series of observations will be required to determine with accuracy the mean light-curve.

In the column headed O — C, is given the comparison of these observations with SCHÖNFELD's elements of this star in his *Zweiter Catalog*. The mean by weights of the residuals indicates a correction of —1ᵈ.52 to the time of the maximum epoch, which, combined with SCHÖNFELD's epoch, gives the correction to the period as —1ᵐ.8.

If these observations are correct, it would appear that the period, which ARGELANDER found to be increasing up to about 1850, and afterwards to be stationary, is now decreasing. This, however, cannot be considered as certain, until verified by future observations.

The light changes at the minimum very gradually, remaining almost stationary for about a day.

Cambridge, 1887 *July* 2.

OBSERVED MAXIMA.

	Cambr. M.T. d	Wt.	O—C d
848	1887 Feb. 10.06	2	—2.43
849	18.52	1	—4.08
850	Mar. 1.70	1	—3.05
851	15.36	1	+0.45
852	24.71	3	—0.35
853	Apr. 3.36	1	—0.86
854	12.59	2	—1.78
856	May 2.17	1	—2.51
857	14.62	1	—0.22

OBSERVED MINIMA.

	Cambr. M.T. d	Wt.	O—C d
848	1887 Feb. 16.73	4	—0.71
849	26.72	4	—0.88
850	Mar. 10.29	1	+0.53
851	19.40	2	—0.51
852	24.70	2	—5.36
853	Apr. 8.71	3	—0.51
854	18.35	1	—1.02
855	28.74	1	—0.79
856	May 9.04	3	—0.65

COMET 1887 *f*.

A circular from Mr. RITCHIE, of the *Science Observer*, announced to astronomers, August 26, the discovery of a comet by BROOKS, early in the morning of the preceding day. The position, as given by the discoverer, was

Aug. 24.8703 Gr. M.T. $\alpha = 128° 15'$, $\delta = +28° 59'$

Mr. EGBERT, at the Dudley Observatory in Albany, from his own observations of August 26, 27 and 28, deduced approximate elements, which he transmitted August 29, calling attention to their resemblance to those of OLBERS's comet of 1815, and to the near accordance of the geocentric path to that given in GINZEL's sweeping-ephemeris.

RING-MICROMETER OBSERVATIONS OF COMET 1887 *f* (*Brooks*),

MADE AT THE VANDERBILT UNIVERSITY OBSERVATORY,

BY E. E. BARNARD.

1887 Nashville M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ
August 27ᵈ 16ʰ 9ᵐ 29ˢ	1	8	—1ᵐ 2ˢ.44	+2′ 54″.2	8ʰ 44ᵐ 16ˢ.9	+29° 36′ 12″.3
28 16 23 52	1	4	+3 15.07	+6 59.3	8 48 34.4	+29 40 17.3

Mean Place for 1887.0 of Comparison-Star.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	8ʰ 45ᵐ 19ˢ.24	+0ˢ.07	+29° 33′ 25″.9	—7″.8	Weisse's Bessel, VIII. 1077

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FILAR-MICROMETER OBSERVATIONS OF COMET 1887 *f* (*Brooks*),

MADE AT THE DUDLEY OBSERVATORY,

BY H. V. EGBERT.

1887 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
Aug. 26 16ʰ 7ᵐ 29ˢ	1	3	−5ᵐ 28ˢ.15	−3′ 6″.4	8ʰ 39ᵐ 51ˢ.22	+29° 30′ 11″.2	n9.698	0.702
27 16 1 48	1	4	−1 12.58	+2 46.5	8 44 6.82	+29 36 4.0	n9.697	0.735
28 15 51 0	2	5	−1 55.78	+2 39.6	8 48 22.09	+29 41 24.1	n9.696	0.747
29 15 49 4	3	6	−3 12.72	−2 31.7	8 52 41.22	+29 46 29.5	n9.696	0.749
30 15 44 51	3	6	+1 8.88	+2 5.6	8 57 2.84	+29 51 6.7	n9.694	0.754

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	8ʰ 45ᵐ 19ˢ.32	+0ˢ.05	+29° 33′ 25″.3	−7″.7	Weisse's Bessel, VIII. 1077
1	8 45 19.32	+0.08	+29 33 25.3	−7.8	Weisse's Bessel, VIII. 1077
2	8 50 17.78	+0.09	+29 38 52.3	−7.8	Argelander, B.B. VI. 29° 1847
3	8 55 53.86	+0.08	+29 49 9.0	−7.8	Leiden Zones, 12,162
3	8 55 53.86	+0.10	+29 49 9.0	−7.9	Leiden Zones, 12,162

ELEMENTS AND EPHEMERIS OF COMET 1887 *f* (*Brooks*),

BY H. V. EGBERT.

From the Albany observations of August 26, 28 and 30, I have derived the following elements:

ELEMENTS.

$$T = 1887 \text{ Oct. } 6.480 \text{ Gr. M.T.}$$
$$\left.\begin{aligned} \omega &= 63^\circ\ 18' \\ \Omega &= 84\ \ 33 \\ i &= 44\ \ 10 \end{aligned}\right\} \text{App. Eq.}$$
$$\log q = 0.08719$$

$$C\text{—}O \quad \begin{aligned} \Delta\lambda \cos\beta &= -0'.05 \\ \Delta\beta &= -0\ .07 \end{aligned}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

			log r	log Δ	Light
Sept. 2	9ʰ 9ᵐ	+30° 2′	0.1239	0.3168	1.14
6	9 27	30 11	0.1164	0.3093	1.21
10	9 46	+30 13	0.1096	0.3025	1.29
Sept. 14	10ʰ 05ᵐ	+30° 05′	0.1036	0.2964	1.37
18	10 25	29 49	0.0983	0.2912	1.44
22	10 44	+29 23	0.0939	0.2868	1.49

Dudley Observatory, 1887 *August* 31.

The computation of a preliminary orbit on August 29 gave elements which were of sufficient accuracy to establish the identity of this comet with OLBERS's of 1815. For the sake of comparison, I add the elements of the OLBERS comet as given by GINZEL.

$$T = 1886 \text{ Dec. } 16.93 \text{ Ber. M.T.}$$
$$\left.\begin{aligned} \Omega &= 84^\circ\ 31'.4 \\ i &= 44\ \ 33\ .6 \\ \pi &= 149\ \ 48\ .7 \end{aligned}\right\} \text{M. Eq. 1887.0}$$
$$\log q\ (1815.0) = 0.08380$$

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THE

ASTRONOMICAL JOURNAL.

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INVESTIGATION OF THE LIGHT-VARIATIONS OF *U OPHIUCHI*,

BY S. C. CHANDLER, JR.

A peculiar interest attaches to this star, its period being the shortest, and its light-fluctuations the most rapid, of the known variables. Its history is briefly as follows. In a note to SCHJELLERUP's catalogue (p. 237) a suggestion of variability is based upon the diversity in the catalogue-magnitudes of various authorities. The actual discovery of variability was, however, made at Cordoba during the work upon the *Uranometria Argentina*. Dr. GOULD states that the observations indicate an oscillation of the magnitude from 6.0 to 6.5, but exhibiting no regular law (*U.A.* p.306). In 1881, Mr. SAWYER's observations established the real character of the variations, which is that pertaining to the variables of the Algol type; but the period assigned was about five and a quarter days, consisting of a light-decrease, occupying eight hours; a stationary light at minimum during about four hours; a light-increase of eight hours; and a stationary maximum brilliancy during the remainder of the period (*Sci. Obs.*, III., 96; *A.N.*, CI., 187). Early in the following year, however, I found that the true period was only $20^h\ 7^m\ 41^s.6$, and that the whole variation was confined to an interval of about four and one-half hours (*Sci. Obs.*, IV., 11; *A.N.*, CII., 371). Later, from two years' observations, and a careful discussion of all the available material, I could find no sensible correction to my first elements, but there appeared to be evidence of anomalies, both in the period and in the light-curve (*A.N.*, CVIII., 55). The results of this unpublished investigation are here communicated, with the addition of more recent observations.

Before treating of the regular series of observations made upon the variable as such, let us collect and examine the following earlier sporadic estimates of magnitude.

Authority.		Date.		Mag.
Lalande	31392	1797	May 24	6
Bremiker	Notes to Berl. Chart			8
Bessel	W. XVII. 143	1822	July 4	7
Lamont	Z. 101	1841	June 25	7
Lamont	Z. 102	1841	June 26	8
Schönfeld	DM. 1°,3408	1853	June 27	5
Schönfeld	DM. 1°,3408	1854	May 26	6
Paris Obs.	Transit Inst.	1857	July 25	6
Paris Obs.	Mural Cir.	1857	July 25	6.7
Gould	Albany List	1861		6.1
Schjellerup	6162	1863	June 9	7.7
Paris Obs.	Merid. Cir.	1869	July 3	6.7
Paris Obs.	Merid. Cir.	1870	June 29	
Paris Obs.	Mural Cir.	1870	July 23	
Heis		1870		6
Rogers	Merid. Cir.	1878	July 7	6.7
Rogers	Merid. Cir.	1878	July 10	5.9
Rogers	Merid. Cir.	1878	July 13	6.2
Rogers	Merid. Cir.	1878	July 16	6.8
Rogers	Merid. Cir.	1878	July 23	6.3

Besides these there are a few photometric observations by PRITCHARD, and in Vol. XIV of the *Harvard Observatory Annals*, and a few estimates by ESPIN; but all of these have proved unserviceable, on account of their inferior order of accuracy. !

Of the data in the above list I have intimately examined BESSEL's and LAMONT's zones, in the same way as is hereafter shown in the case of SCHJELLERUP, with the conclusion that no definite result can be expected from them. On the two nights of SCHÖNFELD's estimates for the DM., the star 1°,3411, which is *g* of my list of comparison-stars, was called $1^M.0$ and $1^M.5$, respectively, fainter than the variable; which tends to indicate that on both occasions the latter may have been at ~~maximum~~ brilliancy. The Bonn mean times (heliocentric) of these observations are 1853 June $27^d\ 10^h\ 53^m.4$, and 1854 May $26^d\ 12^h\ 58^m.8$.

Dr. GOULD has kindly furnished me with the original estimates in 1858 and 1859, for his Albany Catalogue. These were made in the same manner as the estimates for the *Uranometria Argentina*, and are therefore entitled to the same high weight. Unfortunately the record does not supply the exact hour of the observations, which can therefore only be assumed, together with the limits of probable uncertainty, as follows:

Original Record.		Assumed probable	
Est. Mag.	Date.	Albany M.T.	Limit.
6.2	1858 Sept. 13	8^h	$\pm 1^h$
6.0	1859 Mar. 9	$15\frac{1}{2}$	$\pm 2\frac{1}{2}$
6.2	" May 24	$12\frac{1}{2}$	$\pm 3\frac{1}{2}$
6.0	" June 6	10	± 2

The estimated magnitudes very certainly indicate that the star could not have been at or near minimum on either of the above occasions.

The information afforded by these data will in future be of great value, but cannot at present be fully utilized.

The most promising estimate in the foregoing table is that of Schjellerup. This should be carefully weighed on account of its leverage of nearly eight thousand periods from the principal epoch. There were observed at Copenhagen, 1863 June 9, seventy-two stars. Of these Schjellerup 6531 is a component of the binary *70 p Ophiuchi*, and Schjellerup 6925 is a faint star only 3′ from a fifth magnitude. The estimates of their magnitudes, both at Bonn and Copenhagen, must obviously be very uncertain, and were therefore excluded. For the others, the comparison of the Schjellerup and DM. magnitudes is given at the left hand of the table below, where the deficiency of stars of the brighter class has been eked out by stars observed at Copenhagen in the same region, on other nights. These are inclosed in parentheses.

Schj.	DM.	No.	Schj. — DM. Obs.	Schj. — DM. Assumed	Diff.	No.
M	M		M	M	M	
9.5	9.20	5	+0.30	+0.20	±0.0	7
9.0	8.71	27	0.29	.30	0.1	9
8.7	8.43	10	0.27	.30	0.2	13
8.5	8.19	7	0.31	.30	0.3	14
8.3	8.13	3	0.17	.40	0.4	11
8.0	7.73	10	0.27	.40	0.5	7
7.7	7.00	3	+0.70	+0.40	±0.6	2

Schj.	DM.	No.	Schj. — DM. Obs.	Schj. — DM. Assumed	Diff.	No.
M	M		M	M	M	
(7.5	7.0	1)	+0.50	+0.50	±0.7	3
7.0	6.55	2	0.45	.50	0.8	2
(7.0	6.50	5)	0.50	.50	0.9	1
(6.5	6.20	2)	0.30	.40	1.0 to 1.7	0
(6.0	5.73	3)	+0.27	+0.30		
5.0	5.0	1	0.00	.00		
4.0	4.0	1	0.00	0.00	±1.8	var.

Applying the well marked systematic differences to Schjellerup's magnitudes, and classifying the differences of the corrected estimates from those of the DM. in order of the residuals, we have the results in the right-hand portion of the table. It will be seen that, except for the variable, where the difference is $1^M.8$, there is no discordance so large as one unit. The corrected observed magnitude of the variable is 7.3. The known limits of its variation are $6^M.03$ and $6^M.71$; and the sensible fluctuations are all confined to a space of time within two hours of minimum. Carefully weighing all these facts, and making reasonable allowance for error, there seems to me little doubt that at the time of Schjellerup's observation, 1863 June $9^d\ 11^h\ 58^m.4$ Copen. M.T., the star was below its mean brightness, and therefore within one hour and a quarter of minimum. This presumption is at least so strong that we ought to require any adopted theory of the star to conform to this condition, unless sufficiently positive contradictory evidence otherwise appears. I have, therefore, placed it in the following table of observed minima.

Table of Observed Minima.

Epoch.	Observed Minimum. Local Mean Time.	Obs.	Wt.	Light Equat.	O—C
	1863 d h m			m	m
—7885	June 9 11 58.4 Cop.			+7.7	—315.5
4295	1871 Sept. 6 7 10. Cord.	D		+0.3	— 82.8
4288	12 7 0. "	D		—0.4	+ 92.6
4264	Oct. 2 7 30. "	D		—2.9	— 64.6
—3861	1872 Sept. 4 7 15. "	D		+0.6	— 56.4
0	1881 July 17 9 45. Cam.	S	¼	+6.0	— 58.0
+ 75	Sept. 18 7 50. "	S	¼	—0.9	— 36.9
106	Oct. 14 7 30. "	S	¼	—4.3	— 58.8
113	20 5 53. "	S	¼	—4.9	+ 29.8
144	Nov. 15 6 15. "	S	½	—6.9	+ 51.3
150	20 6 10. "	S	½	—7.1	— 0.1
156	25 6 30. "	S	½	—7.3	— 26.5
272	1882 Mar. 2 13 48. "	S	¼	—0.6	+ 5.8
296	22 16 30. "	S	½	+2.0	— 14.2
303	28 13 47. "	S	¼	+2.7	+ 9.6
309	Apr. 2 14 38. "	S	¼	+3 3	+ 15.1
328	18 12 22. "	S	¼	+5.1	— 24.7
333	22 16 25. "	S	¼	+5.4	— 60.5
334	23 13 45. "	S	¼	+5.5	+ 11.9
372	May 25 10 15. "	S	1	+7.5	— 8.4
385	June 5 8 18. "	S	¼	+7.6	+ 14.7
397	15 9 45.0 "	C	¼	+7.6	+ 9.4
403	20 10 36.2 "	C	1	+7.5	+ 14.3
403	1882 June 20 10 44.0 Cam.	S	1	+7.5	+ 22.1
409	25 11 20.3 "	C	4	+7.3	+ 12.0
414	29 15 30.0 "	C	½	+7.2	— 16.8
422	July 6 8 42.5 "	C	2	+6.8	— 6.3
422	6 8 51.6 "	S	1	+6.8	+ 2.8
428	11 9 43.2 "	S	1	+6.5	+ 8.0
433	15 13 47.5 "	C	½	+6.2	— 26.5
434	16 10 19.0 "	S	3	+6.1	— 2.8
446	26 12 4.8 "	C	1	+5.2	+ 9.8
446	26 11 50.0 "	S	1	+5.2	— 5.0
448	28 10 15.2 Ath.	Sch		+5.0	— 17.9
454	Aug. 2 10 57.2 "	Sch		+4.5	— 22.5
459	6 9 35.8 Cam.	S	1	+4.1	— 0.3
465	11 10 24.8 "	C	4	+3.5	+ 1.9
465	11 10 18.3 "	S	2	+3.5	— 4.6
472	17 7 45.5 "	C	½	+2.8	+ 28.1
477	21 11 57.3 "	C	1	+2.4	+ 1.0
478	22 8 2.5 "	C	5	+2.2	— 1.7
490	Sept. 1 9 30.4 "	C	5	+1.0	— 7.3
490	1 9 34.1 "	C	4	+1.0	— 3.6
497	6 6 24.1 "	S	1	+0.2	— 8.3
503	12 7 15.1 "	C	4	—0.4	— 4.1
503	12 7 23.6 "	S	3	—0.4	+ 4.4
509	17 8 0.0 "	C	4	—1.0	— 5.9

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Epoch.	Observed Minimum. Local Mean Time.	Obs.	Wt.	Light Equat.	O—C
	1882 d h m			m	m
509	Sept. 17 8 13.2 Cam.	S	5	—1.0	+ 7.8
528	Oct. 3 6 25.7 "	C	1	—3.0	— 8.4
528	3 6 33.9 "	S	4	—3.0	— 0.2
534	8 7 11.5 "	C	2	—3.6	— 9.4
534	8 7 18.0 "	S	2	—3.6	— 2.9
565	Nov. 3 7 16.0 "	C	1	—6.1	— 5.9
	1883				
787	May 8 11 46.2 "	C	2	+6.7	+ 9.2
812	29 10 33.1 "	S		+7.5	— 15.4
824	June 8 12 23.0 "	C	5	+7.7	+ 2.4
843	24 10 44.1 "	S		+7.4	— 3.0
862	July 10 9 6.7 "	C	4	+6.6	— 7.4
862	10 9 7.1 "	S		+6.6	— 7.0
874	20 10 49.0 "	C	2	+5.8	+ 1.8
880	25 11 18.5 "	C	5	+5.4	— 15.2
880	25 11 14.9 "	S		+5.4	— 18.8
886	30 12 7.0 "	C	5	+4.9	— 13.4
892	Aug. 4 13 3.6 "	C	5	+4.3	— 3.6
892	4 12 56.3 "	S		+4.3	— 10.9
893	5 9 17.6 "	C	5	+4.2	+ 2.7
893	5 9 3.7 "	S		+4.2	— 11.2
899	10 10 8.0 "	C	5	+3.7	+ 6.4

Epoch.	Observed Minimum. Local Mean Time.	Obs.	Wt.	Light Equat.	O—C
	1883 d h m			m	m
899	Aug. 10 9 46.1 Cam.	S		+3.7	— 15.5
918	26 8 29.2 "	C	5	+1.7	— 0.6
918	26 8 4.7 "	S		+1.7	— 25.1
924	31 9 10.9 "	C	5	+1.1	— 5.6
924	31 8 58.0 "	S		+1.1	— 18.5
930	Sept. 5 9 41.7 "	S		0.0	— 22.1
949	21 8 26.6 "	S		—1.6	— 5.0
	1884				
1271	June 17 9 37.2 "	S		+7.6	— 2.8
1277	22 10 29.4 "	S		+7.5	+ 3.6
1302	July 13 9 43.1 "	S		+6.4	+ 3.8
1383	Sept. 19 8 16.7 "	S		—1.3	+ 6.5
1408	Oct. 10 7 22.1 "	S		—3.8	— 2.9
	1885				
1699	June 11 8 25.5 "	S		+7.6	— 6.8
1736	July 12 8 50.5 "	S		+6.4	— 27.7
1798	Sept. 2 9 15.5 "	S		+0.8	— 5.3
1842	Oct. 9 6 40.5 "	S		—3.7	— 23.3
	1886				
2157	June 30 11 2.5 "	S		+7.2	— 13.8
2182	July 21 10 15.5 "	S		+5.7	— 14.6
2257	Sept. 22 8 5.5 "	S		—1.7	— 9.0
2276	Oct. 8 7 0.5 "	S		—3.6	+ 2.5

The Cordoba observations are of a highly important character, and are therefore given in detail, exactly as communicated to me by Dr. Gould in 1882, in the first two columns below, the observer being Mr. Davis.

Cordoba M.T.	Observed Sequence.	M	L	E	Computed Min.	D
d h m		m			d	d
1871 Aug. 5	$a\ c\ f\ V\ h\ k$	6.4	4.0	—4333	Aug. 5.487	
12 11 30	$a\ V\ f\ c\ h\ k$	6.0	6.8	4325	12.197	+0.282
17 10 0	$a\ 3\ V\ c\ f\ 2\ h\ 2\ m\ k$	6.1	6.4	4319	17.229	+0.188
24 7 0	$a\ 2\ V\ 2\ f\ c\ 2\ h\ 3\ k\ m$	6.0	6.8	4311	23.938	+0.354
31 7 15	$a\ 2\ f\ v\ c\ h\ k\ m$	6.2	5.3	4302	31.486	—0.184
Sept. 1 7 15	$a\ 3\ f=c\ V\ h\ k\ m$	6.3	4.3	4301	Sept. 1.325	—0.023
6 7 10	$a\ 3\ f\ \frac{1}{2}\ c\ 2\ h\ \frac{1}{2}\ V\ 2\ k\ m$	6.35	2.6	4295	6.857	—0.058
12 7 0	$a\ 3\ c\ f\ 2\ h\ V\ 2\ k\ m$	6.45	2.3	4288	12.228	+0.064
13 8 0	$a\ 2\ V\ c\ f\ 2\ h\ 3\ k$	6.15	6.6	4287	13.066	+0.267
14 7 10	$a\ 2\ V\ c\ f\ 2\ h\ 3\ k$	6.15	6.6	4286	13.905	+0.394
15 8 0	$a\ 3\ c\ V=f\ 2\ h\ 3\ k$	6.25	5.0	4284	15.582	—0.249
19 8 0	$a\ 3\ c\ f\ V\ h\ 3\ k=m$	6.4	4.0	4280	18.937	+0.396
20 8 30	$a\ 3\ c\ f\ 2\ V\ 2\ h\ 3\ k=m$	6.4	4.0	4278	20.614	—0.260
Oct. 2 7 30	$a\ 3\ c\ 2\ f\ 2\ h\ V\ 2\ m\ k$	6.6	2.1	4264	Oct. 2.356	—0.052
11 8 0	$a\ 3\ V\ c\ f\ 2\ h$	6.1	6.4	4253	11.581	—0.248
1872 Mar. 6	$a\ V\ 2\ h\ c\ 2\ f\ 2\ k\ m$		7.0			
Sept. 4	$108 = 6^{M}.4 \quad 116 = 6^{M}.9 \quad V=$	6.7	2.0	—3861	Sept. 4.342	—0.042

Notation: Nos. in *Ophiuchus*, Uran. Arg.

$a =$ No. 82 $\quad h =$ No. 86 $\quad V =$ No. 110

$c =$ No. 81 $\quad k =$ No. 64

$f =$ No. 108 $\quad m =$ No. 76

The column M gives the magnitude assigned to the variable V by Dr. Gould.

From a combination of all the sequences I have determined the light-scale, $a = 8.7$, $c = 5.6$, $f = 5.0$, $h = 3.1$, $k = 0.6$, $m = 0.0$; whence we have the light of the variable in the column L, in this arbitrary scale. The last three columns give, respectively, the number, E, of the nearest epoch of minimum; the corresponding computed Cordoba mean time of minimum from my elements in *A.N.* 2448 and 2572; and D, the interval between this and the time of each observation. The time of three observations of the series is not given; but for the last of these the conditions of sufficient altitude for observation and of the ending of twilight fix it within moderately narrow limits. I have assumed it to be $7^h\ 15^m$.

Since there is but one observation on each evening we cannot deduce the minimum phases in the usual way. Two courses are therefore open.

(*a*). To determine a normal epoch of minimum from the

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complex of all the observations. Thus, arranging the values of L and D in order of the latter, and taking successive means of each five values, we get

D	L	D	L
$+0^{d}.339$	6.2	$+0^{d}.027$	3.4
0.298	6.6	—0.022	2.7
0.232	5.8	—0.085	3.5
0.156	5.3	—0.130	3.6
+0.091	4.3	—0.173	4.0

Whence we find, graphically, the correction to the assumed elements $O-C = -0^{d}.042 = -60^{m}.0$, corresponding to about the mean epoch $E = -4267$.

(*b*). To adopt for those evenings on which the value of L is very decidedly below its average value — namely, 1871 Sept. 6, Sept. 12, Oct. 2, and 1872 Sept. 4 — the observed times as the actual times of minimum. Thus we have the values given in the table of observed minima on page 130. The corresponding corrections to the assumed elements, are

	E	O—C
	E = —4295	O—C = $-82^{m}.8$
	—4288	+92.6
	—4264	—64.6
	—3861	—56.4
Mean	—4177	—27.8

Both of these processes are reasonable, although I prefer the result (*a*).

The regularly observed minima of the star, to 1886 inclusive, comprise two by Schmidt, thirty-two by Sawyer, and twenty-nine by myself. There are besides a considerable number of sporadic observations by Sawyer, in 1881 and 1882, from which approximate times may be inferred. He has kindly furnished me with all his observations for these years in detail, giving the light of the variable at each observation. From these I have found the times of minimum here given, by exactly the same process as for my own; namely, applying to each observed times the reduction to minimum corresponding to the observed light L, referred to a mean light-curve, and then taking the means of the reduced times, giving the weights, 1 where $L < 6.0$, ½ where $L = 6.0$ to 7.0, and 0 where $L < 7.0$. The mean light-curves thus employed in reducing Sawyer's minima were found from his observations of 1881 and 1882, and in my own case from one which differs but inappreciably from the one hereafter given. In the reduction of the minima from 1883 to 1886, which he has published from time to time, he has adopted exactly the same method. Thus the whole series for both observers is strictly homogeneous in this particular. This makes interesting the comparison of identical minima for the recognition of personal differences in observation, for which so good an opportunity is not often presented. From the sixteen minima common to the two series, the differences Chandler—Sawyer, are

1882 E	1882 C—S	1883 E	1883 C—S
403	$-7^{m}.8$	862	$-0^{m}.4$
422	— 9.1	880	+ 3.6
446	+14.8	892	+ 7.3
465	+ 6.5	893	+13.9
490	— 3.7	899	+21.9
503	— 8.5	918	+24.5
509	—13.2	924	+12.9
528	— 8.2		
534	— 6.5		
Mean	— 4.0	Mean	+12.0

It seems reasonable to attribute the curious change of sign to the fact mentioned by Sawyer (*A.N.* 2591) that during 1883 he was accustomed to employ, in preparing for observation, an approximate ephemeris whose times were fifty minutes less than the known elements gave. This incident is not to be regretted, from the instruction it affords as to the possible influence of mental preoccupation of the sort; and is the more interesting from the well-known high character of the work of this skilful and conscientious observer. It should be remarked that, as the average rate of change in light of this variable is about one step in twenty minutes of time, a difference of twelve minutes corresponds merely to 0.06 of a unit of magnitude, a quantity which requires considerable delicacy of perception to recognize.

For the determination of new elements, the data of the previous table of observed minima were combined to form normal epochs according to the weights given, assuming the weight 3 for Sawyer's minima since 1882, and for Schmidt's. The results for each observer are kept separate. These normal epochs are given in the first five columns below. For Cordoba the alternative values (*a*) and (*b*), already described, are both inserted.

Table of Normal Epochs.

Author.	Minima Included.	Mean Epoch.	O—C I	O—C II	O—C III	p
Sj.		—7885	$-315^{m}.5$	$-302^{m}.3$	$-108^{m}.3$	
G	*a*	—4267	— 60.0	— 49.8	+ 0.7	¼
	b	—4177	— 27.8	— 17.6	+ 30.3	
S	0– 156	+ 120	— 7.5	+ 2.9	— 7.5	½
S	272– 403	350	0.0	+ 6.3	+ 0.4	½
C	397– 446	416	+ 4.3	+ 10.6	+ 4.9	1
Sm	448– 454	451	— 20.2	— 13.9	— 19.5	½
S	422– 490	457	— 2.0	+ 4.3	— 1.3	1
C	465– 497	479	— 1.9	+ 4.3	— 1.2	1
C	503– 565	517	— 6.1	+ 0.1	— 5.2	1
S	503– 534	517	+ 2.5	+ 8.7	+ 3.4	1
C	787– 874	838	+ 0.3	+ 6.3	+ 2.6	1
S	812– 862	839	— 8.5	— 2.5	— 6.2	1
C	880– 893	888	— 7.4	— 1.5	— 4.8	1
S	880– 899	891	— 14.1	— 8.2	— 11.4	1
C	899– 924	914	+ 0.1	+ 5.9	+ 2.9	1
S	918– 949	930	— 17.7	— 11.9	— 14.4	1
S	1271–1408	1328	+ 1.6	+ 7.1	+ 7.5	1
S	1699–1842	1769	— 15.8	— 10.7	— 5.4	1
S	2157–2276	+2218	— 8.7	— 3.9	+ 7.7	1

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The values in column I of (O—C) are the means of those in the table of observed minima, and result from the elements in *A. N.* 2448,

1881 July $17^d\ 10^h\ 49^m\ 0^s$ (Camb. M.T.) + $20^h\ 7^m\ 41^s.6$ E

which are identical with those in *A. N.* 2572,

1884 January $1^d\ 0^h\ 54^m\ 43^s.6$ (Paris M.T.)
+ $20^h\ 7^m\ 41^s.6$ (E — 1070)

From all the normal epochs, except SCHJELLERUP's (employing equation *b* for Cordoba), we find by least squares, using the weights *p*, the corrections to these assumed elements,

Correction to principal epoch, $-6^m.65 \pm 1^m.76$
Correction to period, $+ 0^s.05 \pm 0^s.093$

the latter being insignificant, as well as far less than its probable error. Applying these corrections, we find the values II of (O—C). These show at a glance that SCHJELLERUP's observation is irreconcilable with any value of a uniform period which will tolerably satisfy the other data; and closer attention will show, also, that even disregarding SCHJELLERUP, there is a tendency to system in the residuals II, which is equally suggestive of inconstancy in the period. The solution which best satisfies the equations from 1881 to 1886 gives the correction to the epoch $-4^m.5$, and to the period $-0^s.075$; and increases the residual for SCHJELLERUP to -321^m, and that for GOULD to -61^m (*a*), or to -29^m (*b*). This evidence as to the probable shortening of the period comes out clearly by combining the observations into six principal epochs, thus:

			E	O—C
I	1863	SCHJELLERUP	—7885	—315.5
IIa	1871–2	GOULD	—4267	— 60.0
IIb	1871–2	GOULD	—4177	— 27.8
III	1882	CHANDLER	+ 476	— 1.7
IV	1881–3	SAWYER	+ 665	— 7.0
V	1883	CHANDLER	+ 883	— 3.0
VI	1884–6	SAWYER	+1737	— 6.9

whence from the differences we get

I -IIa	P = $20^h\ 7^m\ 45^s.84$	about the year 1867
I -IIb	46.24	about the year 1867
IIa–III	42.34	" " 1876
IIb–III	41.94	" " 1876
III–V	41.41	" " 1883
IV–VI	41.60	" " 1884

All the data can be well reconciled by assuming the period to shorten with each recurrence by $0^s.0004$. Thus if we add the quantity $0^s.0002\ E^2$ to the residuals O—C in column I, we have column III, where the residuals for Sch. and G are reduced to a reasonable amount, and a perfectly satisfactory alternation of sign is secured for the rest of the series.

A farther corroboration of the existence of this irregularity is that, while the assumption of a uniform period tends to conflict with the Albany estimate of 1858 Sept. 13, the hypothesis of a shortening is in harmony with all four of the Albany estimates, as well as with those at Bonn.

We may therefore adopt, as definitive, the original elements with the addition of this secular term, or

1884 January $1^d\ 0^h\ 54^m\ 43^s.6$ Paris M.T.
+ $20^h\ 7^m\ 41^s.6$ (E — 1070) — $0^s.0002\ E^2$

In the next number of the *Astronomical Journal* will be given a discussion of the light-curve, which presents some interesting peculiarities, and also a general ephemeris, with appropriate subsidiary tables.

ON THE PERIOD OF THE ALGOL-VARIABLE, *Y CYGNI*,

BY EDWIN F. SAWYER.

Since the publication of my article on the above variable, in No. 159 of this Journal, I have obtained farther observations on this star which go to prove that the period, instead of being $2^d\ 23^h\ 56^m$, is only one-half of this, or $1^d\ 12^h \pm$. This contradicts the observation of 1887 January 12, $17^h\ 15^m$ to $18^h\ 5^m$, made by Mr. CHANDLER (No. 150 *Astron. Journal*), when he found the star apparently at maximum. He states, however, that the observation was made in strong morning twilight, and consequently little to be depended upon. Unfortunately, owing to press of other matters, my observations are not continuous enough to establish precisely the times of minima on the several evenings when the star was observed in faint light; consequently no attempt has been made to improve the general elements computed by Mr. CHANDLER.

Cambridgeport, 1887 *September*.

As, however, the star can be continuously observed for some time to come, owing to the minima occurring at intervals of three days at about $7–8^h$, Camb. M.T., observers will soon be able to obtain the necessary data for a more rigid determination of the period. The following table gives the light of the variable at each observation:

1887	Camb. M.T. h	m	Light	1887	Camb. M.T. h	m	Light
Aug. 13	8	50	6.4	Aug 25	8	25	4.6
13	9	55	6.7:	25	10	15	6.8
16	8	45	5.2: hazy	Sept. 4	8	0	10.0
16	9	55	5.2: hazy	5	7	35	10.0
18	8	25	10.0	5	10	1	10.0
18	9	30	10.0	9	8	5	faint: hazy
19	8	35	faint: hazy	9	9	5	faint: hazy
19	9	35	faint: hazy				

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OBSERVATIONS OF COMET 1887 *f* (*Brooks and Olbers*),

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6 INCH EQUATORIAL,

BY PROF. EDGAR FRISBY, U.S.N.

(Communicated by the Superintendent.)

1887 Washington M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Aug. 29 16 24 12.5	1	5 , 1	+2 31.77	+ 7 59.1	8 52 49.61	+29 46 43.2	n9.724	0.673
" 16 24 12.5	2	5 , 1	—3 4.50	— 2 18.2	8 52 50.14	+29 47 0.0		
30 16 1 30.4	3	14 , 8	—0 26.49	+ 8 36.0	8 57 9.02	+29 51 23.6	n0.022	0.711
" 16 16 49.1	4	9 , 2	+1 17.05	+ 2 22.8	8 57 11.01	+29 51 24.0	n0.024	0.685
31 16 31 56.7	5	13 , 3	—1 41.58	— 5 21.7	9 1 37.40	+29 55 27.3	n9.704	0.665
Sept. 16 16 46 24.3	6	11 , 3	—0 30.01	—14 52.6	10 16 48.12	+29 56 11.5	n9.724	0.657
19 16 34 34.0	7	13 , 3	+2 9.77	— 0 50.6	10 31 34.53	+29 41 20.7	n9.723	0.663

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	8 50 17.78	+0.06	+29 38 52.1	—8.0	Bonn, VI.,+29° 1849
2	8 55 54.60	+0.04	+29 49 26.2	—8.0	W. Bessel, VIII. 1321
3	8 57 35.42	+0.09	+29 42 55.5	—7.9	Leiden Zones, 12,83 and 162,103
4	8 55 53.86	+0.10	+29 49 9.1	—7.9	Leiden Zones, 12,80 and 162,102
5	9 3 18.88	+0.10	+30 0 56.9	—7.9	Leiden Zones, 37,3 and 39,5
6	10 17 17.98	+0.15	+30 11 11.5	—7.4	Leiden Zones, 41,54
7	10 29 24.73	+0.03	+29 42 21.2	—9.9	Leiden Zones, 27,5 and 116,119

THE RECENT APPROACH OF THE OLBERS-COMET TO MARS.

The proximity of the OLBERS-comet to *Mars* at the end of last July does not seem as yet to have been noticed. Using the elements given by Dr. KRUEGER, *A. N.* 2803, we have for the heliocentric coordinates of the comet, for Greenwich mean noon and the mean equinox of date, and for those of *Mars* according to the *American Ephemeris*,

Date	Longitude. Comet	Longitude. Mars	Latitude Comet	Latitude Mars	Radius Vector Comet	Radius Vector Mars
	° ′	° ′	° ′	° ′		
July 17	82 57.7	79 41.3	—1 32.5	+0 57.2	1.709	1.549
21	84 27.6	81 42.0	—0 4.0	+1 0.5	1.671	1.554
25	86 1.6	83 41.9	+1 28.5	+1 3.7	1.633	1.559
29	87 40.2	85 41.1	+3 5.4	+1 6.8	1.596	1.564
Aug. 2	89 24.0	87 39.5	+4 46.9	+1 9.8	1.559	1.569

Though the approach hardly seems to have been near enough to very materially affect the elements of the comet, still its effect certainly should be taken into account in comparing its present ellipse with that which it moved in at its previous apparition.

GEORGE M. SEARLE.

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ELEMENTS AND EPHEMERIS OF THE OLBERS-COMET,

By H. V. EGBERT.

When the material for this orbit was being prepared, it was hoped to get a satisfactory normal place near the close of September, but the cloudy weather has prevented this, and the orbit rests in part on rather slender material.

Using the Albany observations of August 27, 28, 29, 30, with Ginzel's ellipse, there was obtained for the time of perihelion, October 8.50398 Gr. M.T. The elements then stood (*V.J.S.* XVII. 113),

$$\begin{aligned} T &= 1887 \text{ Oct. } 8.50398 \text{ Gr. M.T.} \\ \left.\begin{aligned} \Omega &= \;\, 84^\circ\ 31'\ 24''.2 \\ c &= \;\, 44\ \ 33\ \ 34\ .3 \\ \pi &= 149\ \ 48\ \ 40\ .3 \end{aligned}\right\} &\ 1887.0 \\ \phi &= \;\, 68\ \ 31\ \ \ 3\ .0 \\ \mu &= \;\, 49''.387785 \end{aligned}$$

With these elements an ephemeris was formed for the purpose of determining normal places, which were composed as follows:

I.	Aug. 27.	Königsb., Vienna, Rome, Albany, Nashv.
	" 28.	Königsb., Kremsmünster, Albany, Nashv.
II.	" 30.	Milan, Besançon, Lyons, Alb., Washing.
	" 31.	Milan, Turin, Algiers, Washington.
III.	Sept. 6.	Plonsk, Geneva.
IV.	" 14.	Kiel, Strasburg.
	" 15.	Kiel, Albany.
	" 16.	Washington.
V.	" 18.	Kiel.
VI.	" 23.	Albany.

Normal Places, (1887.0)

Greenw. M.T.	α	δ	Corr. to Eph. α	Corr. to Eph. δ
	° ′ ″	° ′ ″	″	″
Aug. 28.0	131 10 4.3	29 37 2.1	− 11.1	+ 6.5
" 31.0	134 25 13.3	29 52 4.8	+ 3.9	+ 5.5
Sept. 6.5	141 45 39.5	30 11 20.5	+ 34.5	+ 7.8
" 15.5	152 28 52.6	30 2 8 9	+ 78.0	− 3.3
" 18.630046	156 19 10.8	29 48 3.0	+ 99.6	− 8.1
" 23.875949	162 48 58.8	29 10 56.2	+181.5	−23.8

The differential coefficients for these dates were formed, and a solution made by least squares, in which Δe was considered as a function of the other increments, and finally derived directly from the normal equations. The final increments were

$$\begin{aligned} \Delta\pi &= +5'\ 55''.8 \\ \Delta\Omega &= -1\ \ 29\ .7 \\ \Delta i &= +1\ \ 19\ .6 \\ \Delta T &= +0^d.045223 \\ \Delta q &= -0\ .0021360 \\ \Delta e &= -0\ .0006647 \end{aligned}$$

and the new elements,

$$\begin{aligned} T &= 1887 \text{ Oct. } 8.549199 \text{ Gr. M.T.} \\ \left.\begin{aligned} \omega &= 65^\circ\ 24'\ 41''.6 \\ \Omega &= 84\ \ 29\ \ 54\ .5 \\ i &= 44\ \ 34\ \ 53\ .9 \end{aligned}\right\} &\ 1887.0 \\ \log q &= 0.078619 \\ \log e &= 9.968420 \end{aligned}$$

These elements represent the six normal places, as follows:

	C—O $\Delta\alpha \cos\delta$	C—O $\Delta\delta$
	″	″
I.	+1.4	−0.1
II.	−1.3	+1.4
III.	−2.6	−2.1
IV.	+2.1	−0.3
V.	−1.9	−1.3
VI.	−1.4	+1.2

Equatorial Coordinates.

$$\begin{aligned} x &= [9.854561]r \sin (v + 237^\circ\ 42'\ 37''.0) \\ y &= [9.972444]r \sin (v + 168\ \ 45\ \ 47\ .7) \\ z &= [9.891718]r \sin (v + \;\,95\ \ 57\ \ 58\ .7) \end{aligned}$$

Ephemeris for Greenwich Midnight (Equin. 1887.0).

1887	α	δ	log r	log Δ	L
	h m s	° ′ ″			
Oct. 16	12 40 22.99	+23 32 11.9	0.08080	0.27546	1.59
18	49 21.93	22 51 20.8			
20	12 58 11.76	22 9 22.7	0.08351	0.27782	
22	13 6 52.07	21 26 27.8			
24	15 22.71	20 42 45.0	0.08724	0.28104	1.50
26	23 43.38	19 58 23.7			
28	31 54.08	19 13 33.0	0.09194	0.28503	
30	39 54.70	18 28 22.6			
Nov. 1	47 45.32	17 43 0.3	0.09752	0.28970	1.38
3	13 55 25.95	16 57 34.7			
5	14 2 56.72	16 12 12.4	0.10391	0.29492	
7	10 17.72	15 27 0.7			
9	17 29.11	14 42 5.6	0.11102	0.30059	1.24
11	24 31.04	13 57 34.3			
13	31 23.70	13 13 31.2	0.11876	0.30660	
15	38 7.26	12 30 1.9			
17	44 41.92	11 47 9.9	0.12703	0.31285	1.08
19	51 7.89	11 4 59.6			
21	14 57 25.38	+10 23 33.3	0.13576	0.31924	

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1887	α	δ	log r	log Δ	L
	h m s	° ′ ″			
23	15 3 34.60	+ 9 42 54.4			
25	9 35.79	9 3 4.7	0.14486	0.32569	0.94
27	15 29.16	8 24 7.2			
29	21 14.95	7 46 2.3	0.15427	0.33212	
Dec. 1	26 53.38	7 8 51.1			
3	32 24.68	6 32 34.4	0.16390	0.33847	0.82
5	37 49.10	5 57 13.5			
7	43 6.77	5 22 48.5	0.17370	0.34466	
9	48 17.89	4 49 20.0			
11	53 22.57	4 16 47.7	0.18363	0.35064	0.70
13	15 58 20.91	3 45 11.5			
15	16 3 13.13	3 14 30.9	0.19362	0.35638	
17	7 59.43	2 44 45.5			
19	16 12 39.93	+ 2 15 55.2	0.20364	0.36182	0.61

Unit of light, August 27.

Dudley Observatory, 1887 *October* 13.

FILAR MICROMETER OBSERVATION OF THE COMET 1887 *f* (*Brooks, Olbers*),

MADE AT THE DUDLEY OBSERVATORY, ALBANY.

By H. V. EGBERT.

1887	Albany M.T.	No. Comp.	☄ — ✱ Δα	☄ — ✱ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
Sept. 23	16ʰ 22ᵐ 14ˢ	2 , 2	—4ᵐ 32ˢ.02	+3′ 30″.0	10ʰ 51ᵐ 17ˢ.56	+29° 10′ 42″.1	*n*9.696	0.736

Mean Place of Comparison-Star.

α	Red. to app. place	δ	Red. to app. place	Authority
10ʰ 55ᵐ 49ˢ.57	+0ˢ.01	+29° 7′ 18″.8	—6″.7	Weisse's Bessel, X. 1085.

TWO HUNDRED SIXTY-NINTH ASTEROID.

A cable-dispatch distributed by Mr. RITCHIE, gives information of an asteroid of the twelfth magnitude, discovered by PALISA, at Vienna, September 21. The position given, is

Sept. 21.5201, Greenw. M.T. $\alpha = 348° 58' 55''.5$, $\delta = —7° 15' 25''$. Daily motion, —0°.13 in α, and 0° 7′ southward.

TWO HUNDRED SEVENTIETH ASTEROID.

A telegram from Mr. RITCHIE announced the discovery of an asteroid of the twelfth magnitude, by PETERS,

Oct. 8.5534 Greenw. M.T. $\alpha = 19° 15' 45''$. $\delta = +12° 26'$.

CORRIGENDA.

No. 158, p. 106. Equation (8), in the value of f, for $2\, r'r'' \cos(v'—v'')$, put $2\, r'r'' \cos\theta'' \cos(v—v'')$.

No. 159, p. 118. Mr. EGBERT has pointed out an error in the right-ascension of the comparison-star no. 28, used at Cordoba for the comet 1886 VII. The minute should be 45, not 54; the star being the same which was used at Plonsk on the following day (*Astr. Nachr.* 116, p. 262), and no. 26 of Washington Transit Zone 190.

No. 160, p. 127. Mr. BARNARD desires that his observation of the comet 1887 f, be corrected, so as to read as follows:

$\Delta\alpha = +3^m 17^s.57$, $\Delta\delta = +8' 34''.0$; $\alpha = 8^h 48^m 36^s.8$, $\delta = 29° 41' 52''.0$.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 162.

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INVESTIGATION OF THE LIGHT-VARIATIONS OF *U OPHIUCHI.*

BY S. C. CHANDLER, JR.

II.

In the last number of the *Astronomical Journal* was given a determination of the period of this star. Coming now to the light-curve, we must, by way of preliminary, describe the formation of the light-scale. This, while nominally determined from my 1882 observations alone, one hundred and seventy-five in number, proved, by subsequent tests with the one hundred and twenty observations in 1883, to require no modification, and it may therefore be regarded as formed from the whole series. Proceeding in the ordinary manner, we find the equations

	No. Obs.		No. Obs.
$a-b = 3.06$	25	$c-d = 1.78$	30
$a-c = 4.50$	10	$c-e = 3.62$	62
$a-d = 4.82$	11	$c-f = 4.60$	34
$b-c = 1.87$	24	$d-e = 2.60$	79
$b-d = 3.13$	31	$d-f = 3.55$	60
$b-e = 4.27$	33	$e-f = 1.50$	29
		$e-g = 3.24$	8

in forming which, only those combinations which involved *sums* of the differences of the variable from the two stars were employed. Although differences of the variable from either star, of four steps and over, were disregarded, there is evidence here that the value of the unit varies slightly with the amount of the light-difference.

Instead of forming the light-scale from these equations, I adopted a method which appears unobjectionable. Although it assumes the light-curve of the variable to be constant, it is entirely independent of its form. Against each observation of the variable, was written the interval of time from the nearest computed minimum. The observations were all arranged in order of this interval, and means were taken, in ten-minute groups, of the observed differences of the variable from each comparison-star. The differences of the means in each group were then taken, for each pair of stars which could be formed without using values of more than two steps; and finally the average of all the values for each pair, giving weights according to the number. Thus were obtained

	No. Obs.		No. Obs.
$a-b = 2.83$	18	$b-d = 2.59$	71
$b-c = 1.52$	77	$c-e = 3.55$	34
$c-d = 1.20$	91	$d-f = 3.52$	81
$d-e = 2.39$	134		
$e-f = 1.20$	95		

equations which are consistent to a satisfactory degree, and which require very little adjustment to form the following light-scale.

	1875.0		L	Mag.
	h m s	° ′		M
a	16 59 6	—0 43.1	10.7	5.83
b	17 1 47	—0 54.8	7.8	6.13
c	17 0 24	—1 29.2	6.3	6.29
d	16 58 55	+0 53.4	5.1	6.42
e	17 9 56	+2 19.7	2.7	6.68
f	17 6 31	+0 30.5	1.5	6.81
g	17 11 17	+1 52.8	0.0	6.97

In the last column, I have placed the carefully assigned equivalent magnitude, in the ordinary historical scale, embodied in the *Uranometria Nova*, the *Durchmusterung*, and the *Uranometria Argentina*.

As no opportunity, when the star could be seen at all near minimum, had been neglected during the two years, the observations were prosecuted under a great variety of conditions; often in bright moonlight, or when considerable haze was present—sometimes with the field-glass, sometimes with the opera-glass. To render their results as homogeneous as possible, the step-value for each evening was ascertained according to the method of SCHÖNFELD and OUDEMANS. For this purpose the ratio of the mean value of the observed differences $b—d$ and $c—e$, for each night, to their values by the light-scale was found, and all the observed differences of the variable from each star altered accordingly. Also, weights were given to the comparison in each observation in proportion to $8—m$, m being the number of steps in each observed light-difference.

In this manner the whole series of two hundred and ninety-five observations was reduced and brought to bear in forming the light-curve. The data for 1882 and 1883 were treated

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independently. The following table gives the values read off from the adjusted curves for each year, with the finally adopted values, and their equivalent magnitudes, in the ordinary scale.

LIGHT-TABLE.

Time.	Before Minimum. 1882	1883	Adopted.		After Minimum. 1882	1883	Adopted.	
h m				M				M
2 40	8.8		8.8 =	6.03	8.8		8.8 =	6.03
30	8.7		8.7	6.04	8.8		8.8	6.03
20	8.4		8.4	6.07	8.5		8.5	6.06
10	8.1		8.1	6.10	8.2		8.2	6.09
2 0	7.8		7.8	6.13	7.9		7.9	6.12
1 50	7.4		7.4	6.18	7.6		7.6	6.16
40	7.0		7.0	6.22	7.3		7.3	6.19
30	6.7	6.9	6.8	6.24	6.8	7.0	6.9	6.23
20	6.3	6.5	6.4	6.28	6.3	6.6	6.4	6.28
10	5.9	6.0	6.0	6.32	5.7	6.2	5.9	6.33
1 0	5.4	5.6	5.5	6.38	4.9	5.5	5.2	6.42
0 50	4.8	5.0	4.9	6.44	4.3	4.5	4.4	6.50
40	4.1	4.4	4.2	6.52	4.1	4.2	4.2	6.52
30	3.5	3.6	3.6	6.58	4.1	3.9	4.0	6.54
20	3.1	2.9	3.0	6.65	3.6	3.3	3.4	6.60
10	2.6	2.5	2.6	6.69	2.9	2.5	2.7	6.68
0 0	2.5	2.2	2.4	6.71	2.5	2.2	2.4	6.71

This light-table presents a peculiarity well worth remark. While before minimum the rate of change is nearly uniform, there is a well-marked retardation in the rate of increase about half an hour after minimum. This interruption appears in the curves of both 1882 and 1883, although more decided in the former. Slight as it is, I did not feel at liberty to neglect it in the drawing, for although it may prove to be subjective, it seems to be an actual result of observation, and not merely accidental. It possesses greater significance from the fact, of which I was not aware until after this discussion was completed, that SCHÖNFELD's light-curve of *S Cancri* reveals a like anomaly. *Algol*, too, has exhibited similar symptoms.

The obvious explanation, that this was merely a subjective phenomenon — due to bias of the observer, who, perceiving that the minimum phase was past, might at first, by unconscious anticipation accelerate, and afterwards compensate by retarding, the light-increase — led me, when it first struck my attention, to avoid sedulously any such anticipatory tendency. But, notwithstanding this, the peculiar behavior of the star appealed too strongly to the eye to be ignored, being equivalent in one or two minima almost to a secondary phase. It should be noted here that the effect is more marked in the individual minima than in the mean light-curve, the mode of whose formation would tend to mask partially an ill-defined phenomenon of this sort, the amount and interval from minimum of which are, either really or apparently, different at different times.

The importance of settling definitively the true nature of this anomaly is manifest; for a demonstration of its objective character would seem to be fatal to the hypothesis of eclipse, which has long afforded a plausible explanation of the Algol-type of variability, but of this type alone.

The comparison of the above light-table with the individual comparisons gives as the probable error of a single observation of the variable by ARGELANDER's method, assuming the number of unknown quantities to be seven, and reckoning 1 magnitude = 11 steps,

from observations in 1882,	±0.053 M
" " in 1883,	±0.062
" " before minimum,	±0.055
" " after minimum,	±0.056
From all the observations,	±0.055

a satisfactory result, considering that so many of the comparisons were made under disadvantageous circumstances.

In conclusion I give the following tables for the reduction and comparison of observations:

LIGHT-EQUATION,

To be added to observed, to obtain heliocentric, time.

Date.		$\odot - 0'.84t$	Eq.	Date.		$\odot - 0'.84t$	Eq.
		°	m			°	m
Jan.	0	281.0	−6.76	July	9	107.1	+6.64
	10	290.2	6.19		19	116.6	5.87
	20	300.4	5.36		29	126.2	4.96
	30	310.6	4.37	Aug.	8	135.8	3.91
Feb.	9	320.7	3.24		18	145.4	2.75
	19	330.8	2.02		28	155.0	1.50
Mar.	1	340.8	−0.73	Sept.	7	164.7	+0.22
	11	350.8	+0.58		17	174.5	−1.06
	21	0.8	1.87		27	184.3	2.32
	31	10.7	3.11	Oct.	7	194.1	3.51
April	10	20.5	4.25		17	204.0	4.60
	20	30.3	5.27		27	214.0	5.55
	30	40.0	6.14	Nov.	6	224.0	6.33
May	10	49.7	6.83		16	234.1	6.92
	20	59.3	7.32		26	244.2	7.30
	30	68.9	7.61	Dec.	6	254.3	7.45
June	9	78.5	7.68		16	264.5	7.37
	19	88.0	7.53		26	274.7	−7.06
	29	97.6	+7.18				

The above table of light-equation is computed from $454^s.0\ R \sin(\odot + 13° 34'.7)$, for the year 1882, but will answer, strictly, for other years by entering with the argument indicated in the second column, where $\odot$ is the sun's true longitude, and t = year — 1882. Generally, however, it will be sufficiently accurate to enter merely with the date.

We may avail ourselves of the following relations of near commensurability of the period $20^h\ 7^m\ 41^s.6$ with the mean solar day,

$$31 \text{ Periods} = 26 \text{ days} - 1^m\ 30^s.4$$
$$434 \text{ Periods} = 364 \text{ days} - 21\quad 5.6$$

to give an ephemeris, in a very compact and convenient form; which, besides serving particularly for 1888, shall also serve as a basis for a general ephemeris, by which the exact computed Greenwich time of minimum on any given day of any year may be very quickly arrived at, by the appended precepts.

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TABLES FROM THE ELEMENTS, 1884 Jan. $1^d\ 0^h\ 45^m\ 22^s.6$. Gr. M.T. $+ 20^h\ 7^m\ 41^s.6\ (E-1070) - 0^s.0002\ E^2$

TABLE I. EPHEMERIS OF *U Ophiuchi* FOR 1888. HELIOCENTRIC GREENWICH M.T.

2843 to 2873	2874 to 2904	2905 to 2935	2936 to 2966	2967 to 2997	2998 to 3028	3029 to 3059	3060 to 3090	3091 to 3121	3122 to 3152	3153 to 3183	3184 to 3214	Greenwich M. T. (h m)
Jan. 26	Feb. 21	Mar. 18	Apr. 13	May 9	June 4	June 30	July 26	Aug. 21	Sept. 16	Oct. 12	Nov. 7	23 56.6
27	22	19	14	10	5	July 1	27	22	17	13	8	20 4.3
28	23	20	15	11	6	2	28	23	18	14	9	16 12.0
29	24	21	16	12	7	3	29	24	19	15	10	12 19.7
30	25	22	17	13	8	4	30	25	20	16	11	8 27.4
31	26	23	18	14	9	5	31	26	21	17	12	4 35.1
Feb. 1	27	24	19	15	10	6	Aug. 1	27	22	18	13	0 42.8
1	27	24	19	15	10	6	1	27	22	18	13	20 50.5
2	28	25	20	16	11	7	2	28	23	19	14	16 58.2
3	29	26	21	17	12	8	3	29	24	20	15	13 5.9
4	Mar. 1	27	22	18	13	9	4	30	25	21	16	9 13.5
5	2	28	23	19	14	10	5	31	26	22	17	5 21.2
6	3	29	24	20	15	11	6	Sept. 1	27	23	18	1 28.9
6	3	29	24	20	15	11	6	1	27	23	18	21 36.6
7	4	30	25	21	16	12	7	2	28	24	19	17 44.3
8	5	31	26	22	17	13	8	3	29	25	20	13 52.0
9	6	Apr. 1	27	23	18	14	9	4	30	26	21	9 59.7
10	7	2	28	24	19	15	10	5	Oct. 1	27	22	6 7.4
11	8	3	29	25	20	16	11	6	2	28	23	2 15.1
11	8	3	29	25	20	16	11	6	2	28	23	22 22.8
12	9	4	30	26	21	17	12	7	3	29	24	18 30.5
13	10	5	May 1	27	22	18	13	8	4	30	25	14 38.2
14	11	6	2	28	23	19	14	9	5	31	26	10 45.9
15	12	7	3	29	24	20	15	10	6	Nov. 1	27	6 53.6
16	13	8	4	30	25	21	16	11	7	2	28	3 1.3
16	13	8	4	30	25	21	16	11	7	2	28	23 9.0
17	14	9	5	31	26	22	17	12	8	3	29	19 16.6
18	15	10	6	June 1	27	23	18	13	9	4	30	15 24.3
19	16	11	7	2	28	24	19	14	10	5	Dec. 1	11 32.0
20	17	12	8	3	29	25	20	15	11	6	2	7 39.7
21	18	13	9	4	30	26	21	16	12	7	3	3 47.4
m +9.0	m +7.5	m +6.0	m +4.5	m +3.0	m +1.5	m 0.0	m −1.5	m −3.0	m −4.5	m −6.0	m −7.5	

TABLE II. For $(21^m\ 5^s.6)\ t$

Argument, t, difference between calendar year and 1888.

Correction $\left\{ \begin{array}{l} \text{positive before} \\ \text{negative after} \end{array} \right\}$ 1888.

t	Corr. (h m)	t	Corr. (h m)	t	Corr. (h m)	t	Corr. (h m)
1	0 21.1	11	3 52.0	21	7 23.0	31	10 53.9
2	0 42.2	12	4 13.1	22	7 44.0	32	11 15.0
3	1 3.3	13	4 34.2	23	8 5.1	33	11 36.1
4	1 24.4	14	4 55.3	24	8 26.2	34	11 57.2
5	1 45.5	15	5 16.4	25	8 47.3	35	12 18.3
6	2 6.6	16	5 37.5	26	9 8.4	36	12 39.4
7	2 27.7	18	5 58.6	27	9 29.5	37	13 0.4
8	2 48.8	18	6 19.7	28	9 50.6	38	13 21.5
9	3 9.8	19	6 40.8	29	10 11.7	39	13 42.6
10	3 30.9	20	7 1.9	30	10 32.8	40	14 3.7

TABLE III. For $0^s.0002\ E^2$

Correction always negative.

E	Corr. (m)	E	Corr. (m)	E	Corr. (m)
200	0.1	2200	16.1	4200	58.8
400	0.5	2400	19.2	4400	64.5
600	1.2	2600	22.5	4600	70.5
800	2.1	2800	26.1	4800	76.8
1000	3.3	3000	30.0	5000	83.3
1200	4.8	3200	34.1	5200	90.1
1400	6.5	3400	38.5	5400	97.2
1600	8.5	3600	43.2	5600	104.5
1800	10.8	3800	48.1	5800	112.1
2000	13.3	4000	53.3	6000	120.0

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Precept I; for any given date in 1888. Enter Table I with the given date, and take the time in the same horizontal line in the last column, applying the correction at the foot of the date column, and also the correction interpolated from Table III. The number of the epoch E can be readily reckoned from the head of the date column in Table I, which gives the number of the first and last epochs in that column.

Example: — What minimum falls on 1888 May 17?

		d	h	m
From Table I,	1888 May	17	13	5.9
" I,			+	3.0
" III, argument E = 2976,			—	29.5
E = 2976, Greenw. M.T. =	1888 May	17	12	39.4

Precept II; for any given date in any year other than 1888. Increase the difference, disregarding sign, between the year and 1888, by the number of complete multiples of 4 contained in it, and also by unity if the given date is in $\left\{\begin{matrix}\text{March to December}\\ \text{January or February}\end{matrix}\right\}$ of a *common* year $\left\{\begin{matrix}\text{before}\\ \text{after}\end{matrix}\right\}$ 1888.

$\left\{\begin{matrix}\text{Subtract}\\ \text{Add}\end{matrix}\right\}$ the number thus found, treated as a number of days, $\left\{\begin{matrix}\text{from}\\ \text{to}\end{matrix}\right\}$ the given date, if $\left\{\begin{matrix}\text{before}\\ \text{after}\end{matrix}\right\}$ 1888, and with the resulting date enter Table I; the time in the last column, after applying the correction at the foot of the date column, and also the corrections in Table II and III, will be the required Greenwich M.T. of the minimum falling on the given date; or on the day following the given date, if in the year 2000, or later. The number of the epoch will be that corresponding to the date with which Table I was entered, $\left\{\begin{matrix}\text{minus}\\ \text{plus}\end{matrix}\right\}$ as many multiples of 434 as the given year is $\left\{\begin{matrix}\text{before}\\ \text{after}\end{matrix}\right\}$ 1888.

Example 1. To find the computed time of the minimum falling on 1882 Aug. 11

	1882 Aug. 11	
	1888	
Difference	6	
No. multiples	1	
Also	1	8
For this date,		Aug. 3

			h	m
	E 3069	Table I gives	13	5.9
434 × 6 =	—2604	" I "	— 0	1.5
		" II "	+ 2	6.6
		" III " (E = 465)	—	0.6
	E = 465	G. M.T. = 1882 Aug. 11 (d)	15 (h)	10.4 (m)

Example 2. To find the computed time of the minimum falling on 1892 Feb. 11

	1892 Feb. 11	
	1888	
Difference	4	
No. multiples	1	
Also	0	5
With this date,		Feb. 16

			h	m
	E 2867	Table I gives	3	1.3
434 × 4 =	+1736	" I "	+0	9.0
		" II "	—1	24.4
		" III " (E = 4603)	—1	10.6
	E = 4603	G.M.T. = 1892 Feb. 11 (d)	0 (h)	35.3 (m)

Cambridge, 1887 *October* 5.

ON A METHOD OF COMPUTING AN ORBIT FROM THREE OBSERVATIONS,

By Rev. GEORGE M. SEARLE.

The special application of this method is to the case of cometary orbits, it being arranged so as to serve for a parabolic hypothesis which can be changed to an elliptical one for the next approximation, should the indications, furnished by the method, point that way.

The unknown quantities selected are first the ratio of the triangles contained by the radii and chords in the orbit between the first and second observations, and the second and third; secondly, the semiaxis major of the orbit.

The assumption of the ratio above mentioned gives, as is well known, a relation between the first and third distance of the body from the earth; a distance for the first observation is then found, by trial, such that, with the third distance deduced from it, the equation for the elapsed time is satisfied by the two radii vectores and intervening angle or chord. Since the ratio of the triangles has been assumed as a basis, it is clear that the direction of the middle radius vector corresponding to this hypothesis is now known; and it must meet the line of sight given by the second observation, and be thus also determined in length. The formulas which give the length of the middle radius vector in terms of the ratio of the triangles, the first distance of the body from the earth, the other radii and included angles, and known quantities, are not new; but as the known quantities are connected with others which are to be used, it will be well to develop them here.

Let then $\lambda, \lambda', \lambda'', \beta, \beta', \beta''$ be three observed longitudes and latitudes of a planet or comet; t, t', t'' the corresponding times; L, L', L'', R, R', R'' the corresponding longitudes of the sun and radii vectores of the earth.

Let r, r', r'' be the radii vectores of the planet; $2f, 2f', 2f''$ the angles between r' and r'', r and r'', r and r' respectively; ρ, ρ', ρ'', the distances from the earth to the planet, projected on the plane of the ecliptic.

Let $r'r'' \sin 2f = n$; $rr'' \sin 2f' = n'$; $rr' \sin 2f'' = n''$;
$R'R'' \sin (L''-L') = N$; $RR'' \sin (L''-L) = N$;
$RR' \sin (L'-L) = N''$.

Let $x, y, z, x', y', z', x'', y'', z''$ be the rectangular coordi-

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nates of the comet or planet, the plane of the ecliptic being that of xy, the positive axis of z running north; that of x to longitude, L; that of y to longitude $L+90°$.

We have then

$$\begin{aligned} y\ &= z\ \ \sin(\lambda - L)\cot\beta \\ y' &= z'\ \sin(\lambda' - L)\cot\beta' - R'\sin(L' - L) \\ y'' &= z''\sin(\lambda'' - L)\cot\beta'' - R''\sin(L'' - L) \end{aligned}$$

Hence
$$\frac{n''}{n'} = \frac{y'z - yz'}{y''z - yz''} =$$
$$= \frac{z'\left[\sin(\lambda' - L)\cot\beta' - \sin(\lambda - L)\cot\beta\right] - R'\sin(L' - L)}{z''\left[\sin(\lambda'' - L)\cot\beta'' - \sin(\lambda - L)\cot\beta\right] - R''\sin(L'' - L)}$$

Similar expressions may be obtained for $\frac{n}{n''}$ and $\frac{n'}{n}$ by putting the axis of x at L' and L''. Multiplying these three, numerator and denominator, by R, R' and R'' respectively, and making

$$\begin{aligned} \sin(\lambda - L\ )\ \cot\beta\ &= m \\ \sin(\lambda' - L')\ \cot\beta' &= m' \\ \sin(\lambda'' - L'')\ \cot\beta'' &= m'' \end{aligned}$$

$$\begin{aligned} -R\ \left[\sin(\lambda' - L\ )\ \cot\beta' - m\ \right] &= a \\ R'\ \left[\sin(\lambda'' - L'\ )\ \cot\beta'' - m'\right] &= a' \\ -R''\left[\sin(\lambda' - L'')\ \cot\beta\ - m''\right] &= a'' \end{aligned}$$

$$\begin{aligned} R\ \left[\sin(\lambda'' - L\ )\ \cot\beta'' - m\ \right] &= b \\ -R'\ \left[\sin(\lambda - L'\ )\ \cot\beta\ - m'\right] &= b' \\ R''\left[\sin(\lambda' - L'')\ \cot\beta'\ - m''\right] &= b'' \end{aligned}$$

we shall have

$$\frac{n''}{n'} = \frac{N'' + az'}{N' - bz''} \qquad \frac{n}{n''} = \frac{N - a'z''}{N'' - b'z} \qquad \frac{n'}{n} = \frac{N' - a''z}{N + b''z'}$$

The following relation exists between a, a', a'', b, b', b'':

$$\begin{aligned} aN - b''N'' = a'N' - bN &= a''N'' - b'N' \\ &= mRN - m'R'N' + m''R''N'' \end{aligned}$$

It can also be shown that

$$\frac{bb'b'' - aa'a''}{aN - b''N''} = \frac{\sin(\lambda'' - \lambda')}{\tan\beta'\tan\beta''} - \frac{\sin(\lambda'' - \lambda)}{\tan\beta\tan\beta''} + \frac{\sin(\lambda' - \lambda)}{\tan\beta\tan\beta'}$$

This quantity we will denote by P.

We will now denote $\frac{n}{n''}$, the ratio for our principal unknown quantity, by ν; make $b'\tan\beta = b_0$, and $a'\tan\beta'' = a_0$.

The equation for $\frac{n}{n''}$ then can be written

$$\rho'' = \nu\,\frac{b_0}{a_0}\cdot\rho + \frac{N - \nu N''}{a_0}$$

or, making $\nu\,\frac{b_0}{a_0} = M$ and $\frac{N - \nu N''}{a_0} = b$,

$$\rho'' = M\rho + l$$

which is the relation between the first and third distances above referred to.

To ascertain the value of ρ corresponding, for any assumed value of ν, to the time, we must have formulas for finding r, r'', and the connecting chord, which we will denote by κ, from given values of ρ, M and l. We will begin with κ.

We have

$$\kappa^2 = \rho^2\sec^2\beta'' + \rho''^2\sec^2\beta'' - 2e\rho\rho'' + g^2 + 2\gamma\rho - 2\gamma''\rho''$$

in which $e = \cos(\lambda'' - \lambda) + \tan\beta\tan\beta''$*, g is the chord in the earth's orbit between the first and third place, and

$$\gamma = g\cos(G - \lambda), \quad \gamma'' = g\cos(G - \lambda''),$$

G being the longitude of the first place seen from the third. g and G are most conveniently obtained by equations

$$\begin{aligned} g\sin(G - L) &= R''\sin(L'' - L) \\ g\cos(G - L) &= R''\cos(L'' - L) - R \end{aligned}$$

Putting now $\rho'' = M\rho + l$ into this expression for κ^2, and making

$$\begin{gathered} \sec^2\beta + M^2\sec^2\beta'' - 2Me = h^2 \\ M\gamma'' - \gamma = \mu \\ \text{and } e - M\sec^2\beta'' = \sigma \\ \frac{\mu + \sigma l}{h} = i \end{gathered}$$

we have

$$\kappa^2 = [h\rho - i]^2 + [g^2 - 2\gamma''l + l^2\sec^2\beta'' - i^2]$$

which we will write $\kappa^2 = u^2 + A^2$

This calculation may with some advantage be arranged as follows:

We have, since $\quad l = \frac{N - \nu N''}{a_0}, \quad \nu = \frac{N - a_0 l}{N''}$

Hence $\quad M = \frac{b_0}{a_0}\cdot\frac{N}{N''} - \frac{b_0}{N''}\cdot l$

Hence $\quad \mu = \frac{b_0}{a_0}\,\frac{N}{N''}\,\gamma'' - \gamma - \frac{b_0}{N''}\,\gamma''\cdot l$

and $\quad \sigma = \left(e - \frac{b_0}{a_0}\cdot\frac{N}{N''}\sec^2\beta''\right) + \frac{b_0\sec^2\beta''}{N''}\cdot l$

which we may write $\quad \sigma = s' + sl$

We have then

$$\mu + \sigma l = \frac{b_0}{a_0}\cdot\frac{N}{N''}\,\gamma'' - \gamma + \left(s' - \frac{b_0\gamma''}{N''}\right)l + sl^2$$

or, as we may again write,

$$\mu + \sigma l = s''' + s''l + sl^2$$
$$i = \frac{s''' + s''l + sl^2}{h}$$

We have also $\quad h^2 = \sec^2\beta - e^2\cos^2\beta'' + \sigma^2\cos^2\beta''$

If then we make

$$e'^2 = \sec^2\beta\sec^2\beta'' - e^2 = \sec^2\beta\sec^2\beta''\sin^2\delta$$

we have $h^2 = [e'^2 + \sigma^2]\cos^2\beta''$; hence it is always positive.

Making then $\quad \tan\varepsilon = \frac{s' + sl}{e'} \qquad h = \frac{e'\cos\beta''}{\cos\varepsilon}$

h is most conveniently taken positive, though it is in fact indifferent. Changing its sign changes those of i, f, f'', c, c'' and u.

For r^2, r''^2, we have

$$\begin{aligned} r^2\ &= \rho^2\ \sec^2\beta + R^2\ - 2\rho\,R\ \cos(\lambda - L\ ) \\ r''^2 &= \rho''^2\sec^2\beta'' + R''^2 - 2\rho''R''\cos(\lambda'' - L'') \end{aligned}$$

putting in the last, $\rho = \frac{u + i}{h}$, and making

$$\begin{aligned} \cos\beta\ \cos(\lambda - L\ ) &= \cos\psi \\ \cos\beta''\cos(\lambda'' - L'') &= \cos\psi'' \end{aligned}$$

$$\begin{aligned} R\ \sin\psi\ &= B & \qquad h\cos\beta &= f \\ -R\ \cos\psi\ &= C & \qquad \frac{h\cos\beta''}{M} &= f'' \\ R''\sin\psi'' &= B'' & \qquad i + f\ C &= c \\ -R''\cos\psi'' &= C'' & \qquad i + f''\,C'' + f''l\sec\beta &= c'' \end{aligned}$$

* $e = \sec\beta\sec\beta''\cos\delta$, denoting by δ the angle between the first and third geocentric places of the heavenly body.

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we have $r^2 = \left(\frac{u+c}{f}\right)^2 + B^2 \qquad r''^2 = \left(\frac{u+c''}{f''}\right)^2 + B''^2$

These formulas are similar to those of OLBERS's method; but the quantities in some cases have a different meaning, and there are a greater number which are computed once for all.

The value of u can now be varied till the parabolic or elliptic equation for time is satisfied. Some assumption must here be made as to the parabolic or elliptic form of the orbit. Indications of hyperbolic motion are hardly worth attending to.

We next have f' from r, r'' and κ, and, making $\tan\vartheta = \nu\frac{r}{r''}$,

$$\tan(f-f'') = \tan(\vartheta - 45°)\tan f'$$

We have now to deduce r'. The object of this is to find, from the three places where the lines of observation cut the plane determined by ρ and ρ'', the form of the orbit and value of the semiaxis major, which can be ascertained independently of the times; also to obtain values of η and η'', the ratios of the sectors in orbit between the second and third, and first and second places, respectively, to the corresponding triangles. Having obtained them, we shall have

a new value for $\nu = \frac{\eta''}{\eta}\,\frac{(t''-t')}{(t'-t)}$

We have then from the equations for $\frac{n''}{n'}$ and $\frac{n'}{n}$ above, eliminating z',

$$\frac{n'}{n''}\,[aN - b''N''] = bb''z'' - b''N' - \nu[aa''z - aN']$$

Putting now for z'' its value $\nu\,\frac{b'}{a'}\cdot z + \frac{N-\nu N''}{a'}$, we have

$$\frac{n'}{n''}\,[aN - b''N''] =$$

$$= \nu\left(aN' - \frac{bb''}{a'}N''\right) + \nu z\left(\frac{bb'b''}{a'} - aa''\right) - \left(b''N' - \frac{bb''}{a'}N\right)$$

Writing the coefficient of ν,

$$\frac{a(a'N' - bN) + b(aN - b''N'')}{a'},$$

and remembering that $\qquad a'N' - bN = aN - b''N''$,

we have, denoting $\frac{a+b}{a'}$ by Q, $\frac{bb'b'' - aa''a'}{a'[aN - b''N'']}\tan\beta$ by Q',

and $\;-\frac{b''}{a'}$ by Q'',

$$\frac{n'}{n''} = Q\,\nu + Q'\nu\rho + Q'' \qquad \text{or}\ \frac{n'}{n} = Q + Q'\rho + Q''\nu^{-1}$$

This may be written

$$r' = \frac{r''\sin 2f'\operatorname{cosec} 2f''}{Q\nu + Q\nu'\rho + Q''} = \frac{r\sin 2f'\operatorname{cosec} 2f}{Q + Q'\rho + Q''\nu^{-1}}$$

For a check we may compute, once at least,

$$z' = \frac{Nz + N''z'' - (a'+b')zz''}{N' - (a''+b'')z - (a+b)z'' - Pzz''},$$

z and z'' being obtained from ρ and ρ''; then $\rho' = z'\cos\beta'$;

$$r'^2 = \rho'^2\sec^2\beta' + R'^2 - 2R'\rho'\cos(\lambda' - L')$$
$$\text{or}\qquad = z'^2\operatorname{cosec}^2\beta' + R'^2 - 2R'\cos(\lambda' - L')\cot\beta'\cdot z'$$

From r, r', r'' and the intervening angles, the semiaxis minor, b, can be deduced by making

$$S = \frac{\sin f}{r\sin f'\sin f''},\quad S' = \frac{\sin f'}{r'\sin f''\sin f},\quad S'' = \frac{\sin f''}{r''\sin f\sin f'}$$

Then making $\quad S_0 = S' - (S + S''),\qquad$ we have

$$b^{-2} = SS'' - \tfrac{1}{4}S_0^2$$

We also have, for the parameter p, the equation

$$p = \frac{2}{S\cot f - S'\cot f' + S''\cot f''}$$

Hence we should have for a

$$a = \frac{S\cot f - S'\cot f' + S''\cot f''}{2\,SS'' - \frac{1}{2}S_0^2}$$

But as p can on the whole be better determined from the time, the following formulas may be used instead, though the one above gives the value strictly corresponding to the three places, and is good when the angles are large.

We have for η', the ratio of the sector, between r, r'' and the orbit, to the triangle between $r\,r''$ and κ, the expression

$$\eta' = 1 + \frac{4w'}{3}[\sin^2\tfrac{1}{2}\chi\sec\chi + \sin^2\tfrac{1}{2}g']$$

in which $\chi = \sin^{-1}\frac{\kappa}{r+r''}$ and g' is half the difference of eccentric anomaly between r and r', and equal to $\frac{\varepsilon-\delta}{2}$ in the equation

$$(\varepsilon - \delta) - (\sin\varepsilon - \sin\delta) = \kappa(t''-t)\,a^{-\frac{3}{2}}$$

and $w' = \frac{1}{1 - \frac{6}{5}(\sin^2\frac{1}{2}g' - \xi')}$, ξ' having the meaning given to it in the *Theoria Motus*.

Then η' being obtained, we have

$$\sqrt{p} = \frac{\eta'\,rr''\sin 2f'}{k(t''-t)} \qquad\text{and}\qquad a^{-1} = b^{-2}p.$$

To obtain η and η'' we compute g and g'' from the formulas

$$\sin^2 g = \frac{b^{-2}}{S'}\cdot\frac{1}{S''} \qquad\qquad \sin^2 g'' = \frac{b^{-2}}{S'}\cdot\frac{1}{S}$$

Then $\qquad \eta = 1 + \frac{2\sqrt{r'}}{3p}w.\ \sqrt{r''}\sin f\tan f$

$$\eta'' = 1 + \frac{2\sqrt{r'}}{3p}w''\sqrt{r}\sin f''\tan f''$$

Then ν for the next hypothesis $= \frac{\eta''}{\eta}\,\frac{(t''-t')}{(t'-t)}$

The logarithm of w will have nearly a constant ratio to

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the natural quantity $\sin^2 g$. Putting then this ratio $= W$, we have

$$\log w = W \sin^2 g$$

or

$$\log . \log w = \log W + \log \sin^2 g$$

or approximately, for moderate values of g,

$$= \log \sin^2 g + 0.1707 \sin^2 g - 0.88514$$

The following is a table of $\log W$ for argument $\sin^2 g$.

$\sin^2 g$	$\log W$	$\sin^2 g$	$\log W$	$\sin^2 g$	$\log W$	$\sin^2 g$	$\log W$
0.000	9.11486	0.010	9.11657	0.020	9.11827	0.030	9.11998
.001	11503	.011	11674	.021	11844	.031	12015
.002	11520	.012	11692	.022	11861	.032	12032
.003	11537	.013	11709	.023	11878	.033	12049
.004	11554	.014	11726	.024	11895	.034	12066
.005	11571	.015	11743	.025	11912	.035	12084
.006	11588	.016	11760	.026	11930	.036	12101
.007	11606	.017	11776	.027	11947	.037	12118
.008	11623	.018	11793	.028	11964	.038	12135
0.000	9.11640	0.019	9.11810	0.029	9.11981	0.039	9.12152

Recapitulation of Formulas for Practical Computation.

$$N = R'R'' \sin(L''-L')$$
$$N' = R R'' \sin(L''-L)$$
$$N'' = R R' \sin(L'-L)$$

$$m' = \sin(\lambda'-L') \cot \beta'$$

$$a_0 = R' [\sin(\lambda''-L') - m' \tan \beta'']$$
$$b_0 = R' [m' \tan \beta - \sin(\lambda-L')]$$

$$Q_0 = \frac{R''}{N} [\sin(\lambda''-L'') - \sin(\lambda'-L'') \tan \beta'' \cot \beta']$$

$$Q' = \frac{1}{a_0} \left(\sin(\lambda''-\lambda') \frac{\tan \beta}{\tan \beta'} + \sin(\lambda'-\lambda) \frac{\tan \beta''}{\tan \beta'} - \sin(\lambda''-\lambda) \right)$$

$$e = \cos(\lambda''-\lambda) + \tan \beta \tan \beta''$$
$$e' = + \sqrt{\sec^2 \beta \sec^2 \beta'' - e^2}$$

$$\cos \psi = \cos \beta \cos(\lambda-L)$$
$$\cos \psi'' = \cos \beta'' \cos(\lambda''-L'')$$

$$\left. \begin{array}{l} B = R \sin \psi \\ B'' = R'' \sin \psi'' \end{array} \right\} \text{always positive}$$

$$C = - R \cos \psi$$
$$C'' = - R'' \cos \psi''$$

$$g \sin(G-L) = R'' \sin(L''-L)$$
$$g \cos(G-L) = R'' \cos(L-L) - R$$

$$\gamma = g \cos(G-\lambda)$$
$$\gamma'' = g \cos(G-\lambda'')$$

$$s = \frac{b_0}{N''} \sec^2 \beta''$$

$$s' = e - \frac{N}{a_0} s$$

$$s'' = s' - \frac{b_0}{N''} \gamma''$$

$$s''' = \frac{N}{a_0} \cdot \frac{b_0}{N''} \gamma'' - \gamma$$

These quantities are computed once for all.

For the first hypothesis, if no better value is known, take $\nu = \frac{N}{N''}$, so that $l = o$; and assume a parabolic orbit or some value of the semiaxis major.

For each hypothesis compute

$$M = \nu \frac{b_0}{a_0}; \qquad l = \frac{N - \nu N''}{a_0}$$

$$\tan \varepsilon = \frac{s' + sl}{e'} \qquad h = \frac{e' \cos \beta''}{\cos \varepsilon} \qquad i = \frac{s''' + s''l + sl^2}{h}$$

$$A^2 = g^2 - 2 \gamma'' l + l^2 \sec^2 \beta'' - i^2$$

$$f = h \cos \beta \qquad c = i + f C$$

$$f'' = \frac{h \cos \beta''}{M} \qquad c'' = i + f'' C'' + f'' l \sec \beta''$$

Then determine κ, r, and r'', by assuming u, and making

$$\tan \sigma = \frac{u}{A} \qquad \kappa = \frac{A}{\cos \sigma}$$

$$\tan \zeta = \frac{u+c}{fB} \qquad r = \frac{B}{\cos \zeta}$$

$$\tan \zeta'' = \frac{u+c''}{f'' B''} \qquad r'' = \frac{B''}{\cos \zeta''}$$

and satisfying the equation for time

$$(r+r''+\kappa)^{\frac{3}{2}} - (r+r''-\kappa)^{\frac{3}{2}} = 6k(t''-t)$$

or

$$(\varepsilon - \delta) - (\sin \varepsilon - \sin \delta) = k(t''-t) a^{-\frac{3}{2}}$$

in which

$$\sin^2 \tfrac{1}{2} \varepsilon = \frac{r+r''+\kappa}{4a} \qquad \sin^2 \tfrac{1}{2} \delta = \frac{r+r''-\kappa}{4a}$$

We have then

$$\cos^2 f' = \frac{(r+r''+\kappa)(r+r''-\kappa)}{4rr''}$$

or

$$\sin^2 f' = \frac{(\kappa+r-r'')(\kappa+r''-r)}{4rr''}$$

$$\tan \vartheta = \nu \frac{r}{r''} \qquad \tan(f-f'') = \tan(\vartheta - 45^\circ) \tan f'$$

Then

$$\rho = \frac{u+i}{h}, \quad r' = \frac{r \sin 2f' \operatorname{cosec} 2f}{N^{-1} N' + Q_0 \nu^{-1} l + Q' \rho}$$

$$S = \frac{\sin f}{r \sin f' \sin f''}, \quad S' = \frac{\sin f'}{r' \sin f'' \sin f}, \quad S'' = \frac{\sin f''}{r'' \sin f \sin f'}$$

$$S_0 = S' - (S+S'') \qquad b^{-2} = SS'' - \tfrac{1}{4} S_0^2$$

[The computation of S, S', S'' and b need not be made in

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a parabolic hypothesis till one or two approximations have been made for r; it then gives a test for ellipticity.]

$$\sin\chi = \frac{\kappa}{r+r''} \qquad \eta' = 1+\frac{4w'}{3}\left[\sin^2\tfrac{1}{2}\chi\sec+\chi\sin^2\tfrac{1}{2}g'\right]$$

in which $g' = \tfrac{1}{2}(\epsilon-\delta)$ and is zero for the parabola; w' is equal to unity for the parabola, as also w and w''.

$$p = \frac{\eta' r r'' \sin 2f'}{k(t''-t)}$$

If b has been computed; then

$$\sin^2 g = \frac{b^{-2}}{S'}\cdot\frac{1}{S''} \qquad \sin^2 g'' = \frac{b^{-2}}{S'}\cdot\frac{1}{S}$$

Then
$$\eta = 1+\frac{2\sqrt{r'}}{3p}\,w\sqrt{r''}\sin f\tan f$$

$$\eta'' = 1+\frac{2\sqrt{r'}}{3p}\,w''\sqrt{r}\sin f''\tan f''$$

Then for the next hypothesis $\nu = \dfrac{\eta''}{\eta}\,\dfrac{(t''-t')}{(t'-t)}$

and a^{-1} " " $= b^{-2}p$.

in which, and above, we may compute p if the angles are tolerably large, or as a check for the final approximations, by the formula

$$p = \frac{2}{S\cot f - S'\cot f' + S''\cot f''}$$

Finally, ρ and $\rho'' = M\rho + l$ having been correctly obtained, with the semiaxis major, the elements are easily computed by any method preferred.

TWO HUNDRED SEVENTY-FIRST ASTEROID.

A planet of the eleventh magnitude was discovered by KNORRE at Berlin, October 13. Its position was subsequently determined as follows:

October 16.5219 Greenw. M.T. $\alpha = 18^\circ\ 8'\ 12''$ $\delta = +\ 12^\circ\ 1'\ 32''$ Daily motion in α $-0^\circ\ 12'$; in δ $0^\circ\ 4'$ southward.

EPHEMERIS FOR MINIMA OF THE TWO NEW ALGOL-VARIABLES.

BY S. C. CHANDLER, JR.

Y Cygni; $20^h\ 46^m\ 16^s$, $+34^\circ\ 7'.0$ (1875)

E.	Greenwich M.T. 1887	d	h	m	E.	Greenwich M.T. 1887	d	h	m
224	Nov.	9	23	17.7	241	Dec.	5	10	23.3
225		11	11	14.5	242		6	22	20.1
226		12	23	11.3	243		8	10	16 9
227		14	11	8.1	244		9	22	13.7
228		15	23	4.9	245		11	10	10.5
229		17	11	1.7	246		12	22	7.3
230		18	22	58.5	247		14	10	4.1
231		20	10	55.3	248		15	22	0.9
232		21	22	52.1	249		17	9	57.7
233		23	10	48.9	250		18	21	54.5
234		24	22	45.7	251		20	9	51.3
235		26	10	42.5	252		21	21	48.1
236		27	22	39.3	253		23	9	44.9
237		29	10	36.1	254		24	21	41.7
238		30	22	32.9	255		26	9	38.5
239	Dec.	2	10	29.7	256	Dec.	27	21	35.3
240		3	22	26.5					

R Canis Majoris; $7^h\ 13^m\ 49^s$, $-16^\circ\ 9'.7$ (1875)

E.	Greenwich M.T. 1887	d	h	m	E.	Greenwich M.T. 1887	d	h	m
203	Nov.	12	5	49.5	220	Dec.	1	13	20.1
204		13	9	5.5	221		2	16	36.0
205		14	12	21.4	222		3	19	52.0
206		15	15	37.3	223		4	23	7.9
207		16	18	53.2	224		6	2	23.8
208		17	22	9.1	225		7	5	39.7
209		19	1	25.0	226		8	8	55.6
210		20	4	41.0	227		9	12	11.6
211		21	7	56.9	228		10	15	27.7
212		22	11	12.8	229		11	18	43.3
213		23	14	28.7	230		12	21	59.2
214		24	17	44.6	231		14	1	15.2
215		25	21	0.6	232		15	4	31.1
216		26	0	16.5	233		16	7	47.0
217		28	3	32.4	234		17	11	2.9
218		29	6	48.3	235	Dec.	18	14	18.8
219	Nov.	30	10	4.2					

The particulars of the new determination of the elements on which the above ephemerides are based will be given in a subsequent number of this Journal.

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THE

ASTRONOMICAL JOURNAL.

No. 163.

VOL. VII. BOSTON, 1887 NOVEMBER 19. NO. 19.

ON THE INEQUALITIES OF LONG PERIOD IN THE MOON'S MOTION ARISING FROM THE ACTION OF *VENUS*.

BY JOHN N. STOCKWELL.

1. In the year 1846 HANSEN announced that he had discovered two inequalities of long period in the moon's motion arising from the attraction of *Venus*. Astronomers had long sought in vain for such theoretical inequalities in the moon's motion, but had been unable to find any depending on the action of either the sun or planets. The discordances between the accepted theory of the moon's motion and observation, had long been such as to favor the belief in the existence of such inequalities; and hence astronomers welcomed this announcement by HANSEN as putting a finishing touch to a theory that had exercised the ingenuity of mathematicians and astronomers during nearly two centuries.

These inequalities were duly incorporated as legitimate parts of the lunar tables; and the elements of the moon's orbit were corrected so as to be in conformity with them. The tables thus rectified seemed to represent with great precision the observed places of the moon during a long series of years; and it was confidently predicted that no further corrections to the theory and tables of the moon's motion would be required. The authority on which the existence and amount of these inequalities rested seemed to be a sufficient guarantee of their legitimacy; and it was nearly a dozen years before any attempt was made to verify them by other astronomers. In the mean time the new tables had been published and used in the computations of the Nautical Almanacs and other astronomical ephemerides.

2. The periods of these inequalities are two hundred and seventy-three years and two hundred and thirty-nine years respectively; and the variable parts of the arguments are, for the first inequality, *the moon's mean anomaly plus sixteen times the earth's mean longitude* minus *eighteen times the mean longitude of Venus;* and *eight times the mean longitude of Venus* minus *thirteen the mean longitude of the earth*, for the second inequality.

HANSEN found for the coefficient of the first inequality, $16''.0$; afterwards $27''.4$, and finally in his *Tables of the Moon* gave $15''.34$ as its value. For the second inequality, he first gave $23''.2$ as the value of the coefficient, but afterwards reduced it to $21''.47$. He also characterizes the determination of these inequalities as the most difficult matter which presents itself in the theory of the moon's motion. HANSEN merely announces the values of the coefficients of these inequalities, but I am not aware that he anywhere gives the analysis by which they were determined.

3. DELAUNAY is the only other astronomer who has busied himself with the determination of these inequalities. In the *Additions à la Connaissance des Temps* for 1862 DELAUNAY has given a detailed calculation of the first of these inequalities; and has found its value to be $16''.02$, which is very nearly the same as first found by HANSEN. And in the same work for 1863 DELAUNAY has also given a similar calculation of the second inequality, from which he finds its value to be only $0''.2723$, which is wholly insignificant in comparison with the value found by HANSEN. In Vol. XXIV of the *Proceedings of the American Association for the Advancement of Science*, the writer has given the result of a calculation of the second inequality referred to, in which he obtains a value identical with that of DELAUNAY; and it is generally conceded at the present time that the coefficient of the second inequality, as determined by DELAUNAY, is theoretically correct.

Although the close agreement of the results of HANSEN and DELAUNAY, in regard to the value of the coefficient of the first inequality, would seem to be very strong presumptive proof of its correctness, unless both were similarly vitiated by some systematic error, and might properly excuse any further investigations as to its true value, I have, nevertheless, been tempted to apply a different method of investigation to the problem, from that employed by DELAUNAY; and have obtained results of sufficient importance to merit the further consideration of astronomers. DELAUNAY has very systematically executed his calculations, carrying his approximations to terms of the second order depending on the disturbing masses; and has published them in such

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shape that the different terms of any order may be readily compared with each other.

4. DELAUNAY's calculations show that the terms of the second order, with respect to the masses, are nearly insensible in comparison with those of the first order; and for this reason I have in this investigation restricted my calculations wholly to terms of the first order. The calculations are necessarily divided into two parts. In the first part, I have given the calculations requisite for determining the values of the forces arising from the attraction of the planet on the moon; and, in the second part, I have given the calculation of the effect of these forces on the motion of the moon. I have the satisfaction of finding a perfect agreement between my results and those of DELAUNAY in so far as the determination of the forces is concerned; but in the calculation of the effects of these forces on the moon's motion I have obtained a totally different value; inasmuch as I find the coefficient of the inequality to be only 0″.0192, whereas DELAUNAY has found 16″.02 for the coefficient, which is nearly *nine hundred times greater*. The cause of this discrepancy will be fully explained in the course of this investigation.

5. We shall now investigate the forces by which the planet acts upon the moon; and for this purpose we shall resume the consideration of equations (8) and (10) which we have given in No. 158 of this Journal, namely

$$(1)\quad f=\{r'^2+r''^2-2r'r''\cos\theta''\cos(v'-v'')\}^{\frac{1}{2}};$$

$$\begin{aligned}(2)\quad R=-\frac{m''}{f}-\frac{m''r^2}{4f^3}+\frac{3m''r^2\sin^2\theta}{4f^3}-\tfrac{3}{2}\frac{m''r^2}{f^5}\Big\{&\tfrac{1}{4}r^2-\tfrac{1}{2}r''^2\cos^2\theta\sin^2\theta''-rr''\sin\theta\sin\theta''+\tfrac{1}{2}r''^2\cos^2\theta\cos^2\theta''\cos 2(v-v'')\\ &+\cos\theta\{2r''^2\sin\theta\sin\theta''\cos\theta''-rr''\cos\theta''\}\cos(v-v'')+\tfrac{1}{2}r'^2\cos^2\theta\cos 2(v-v')\\ &+\{rr'-2r'r''\sin\theta\sin\theta''\}\cos\theta\cos(v-v'')-r'r''\cos^2\theta\cos\theta''\cos(2v-v'-v'')\Big\}\end{aligned}$$

In these equations m'' denotes the planet's mass, and f denotes its distance from the center of the earth; r, v and θ denote the moon's geocentric polar coordinates; and the same letters with one and two accents designate the heliocentric coordinates of the *earth* and *Venus* respectively. If we designate the mean longitudes of the *moon*, *earth* and *Venus* by nt $n't$ $n''t$ respectively, the argument of the proposed inequality must contain the terms $nt+16n't-18n''t$, together with one or more terms which are functions of the the perihelia and nodes of the different orbits. In this investigation we shall neglect the inclination of the moon's orbit to the ecliptic, which is taken as the fundamental plane; we shall also neglect the terms of the second order with respect to the disturbing masses, together with those which have the ratio of the moon's distance to that of the sun for a multiplier; and by this means the value of R will become

$$(3)\qquad R=-\frac{m''r^2}{4f^3}+\tfrac{3}{4}\frac{m''r^2}{f^5r''^2}\sin^2\theta''.$$

In order to develop this equation it is necessary to expand the value of f in the form of an infinite series of the multiples of the angle $v'-v''$. We may put the value of f under the following form:

$$f=r'\{1+\frac{r''^2}{r'^2}-2\frac{r''}{r'}\cos\theta''\cos(v'-v'')\}^{\frac{1}{2}}.\qquad(4)$$

This equation may be developed in terms of the variable ratio $\frac{r''}{r'}$ and the multiples of the true difference of longitudes v' and v''; and then corrections may be applied so as to take into account the ellipticities of the orbits. As this is the method of development employed by DELAUNAY, we shall, in order to be wholly independent of what has been published on the subject, proceed in an entirely different manner. The ecliptic being the fundamental plane, we shall put i'' for the inclination, and Ω'' for the longitude of the node, of the orbit of *Venus* on that plane. We shall retain in the calculations quantities of the order e'^2, $e'e''$, e''^2 and γ''^2, in which e' and e'' denote the eccentricities of the orbits of the *earth* and *Venus* respectively; and $\gamma''=\tan i''$. Then we shall have in terms of the mean motions

$$r'=a'\{1+\tfrac{1}{2}e'^2-e'\cos(n't-\omega')-\tfrac{1}{2}e'^2\cos 2(n't-\omega')\},\quad(5)$$

$$r''=a''\{1+\tfrac{1}{2}e''^2-e''\cos(n''t-\omega'')-\tfrac{1}{2}e''^2\cos 2(n''t-\omega'')\},\quad(6)$$

$$v'=n't+2e'\sin(n't-\omega')+\tfrac{5}{4}e'^2\sin 2(n't-\omega'),\quad(7)$$

$$(8)\qquad v''=n''t+2e''\sin(n''t-\omega'')+\tfrac{5}{4}e''^2\sin 2(n''t-\omega'')-\tfrac{1}{4}\gamma''^2\sin 2(n''t-\Omega''),$$

$$(9)\quad \cos\theta''=1-\tfrac{1}{4}\gamma''^2+\tfrac{1}{4}\gamma''^2\cos 2(n''t-\Omega'').$$

If we substitute these values in equation (1) it will become

$$\begin{aligned}f^2=\;&a'^2+a''^2-2a'a''\cos(n't-n''t)+a'^2\{\tfrac{3}{2}e'^2-2e'\cos(n't-\omega')-\tfrac{1}{2}e'^2\cos 2(n't-\omega')\}\\ &+a''^2\{\tfrac{3}{2}e''^2-2e''\cos(n''t-\omega'')-\tfrac{1}{2}e''^2\cos 2(n''t-\omega'')\}\\ &-2a'a''\Big\{\tfrac{1}{2}e'\cos(2n't-n''t-\omega')-\tfrac{3}{2}e'\cos(n''t-\omega')-\tfrac{3}{2}e''\cos(n't-\omega'')+\tfrac{1}{2}e''\cos(n't-2n''t+\omega'')\\ (10)\qquad&-\tfrac{1}{2}\{e'^2+e''^2+\tfrac{1}{2}\gamma''^2\}\cos(n't-n''t)+\tfrac{3}{8}e'^2\cos(3n't-n''t-2\omega')+\tfrac{1}{8}e'^2\cos(n't+n''t-2\omega')\\ &+\tfrac{1}{8}e''^2\cos(n't+n''t-2\omega'')+\tfrac{3}{8}e''^2\cos(n't-3n''t+2\omega'')-\tfrac{3}{4}e'e''\cos(2n't-\omega'-\omega'')\\ &-\tfrac{3}{4}e'e''\cos(2n''t-\omega'-\omega'')+\tfrac{1}{4}e'e''\cos(2n't-2n''t-\omega'+\omega'')+\tfrac{9}{4}e'e''\cos(\omega'-\omega'')+\tfrac{1}{4}\gamma''^2\cos(n't+n''t-2\Omega'')\Big\}\end{aligned}$$

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If we now put
$$\alpha = \frac{a''}{a'} \tag{11}$$
$$\Delta^2 = 1 + \frac{a''^2}{a'^2} - 2\frac{a''}{a'}\cos(n't - n''t) = 1 + \alpha^2 - 2\alpha\cos(n't - n''t), \tag{12}$$

equation (10) will give,

$$\begin{aligned}
\frac{1}{f^3} = \frac{1}{a'^3\Delta^3}\Big\{ 1 + \frac{1}{\Delta^2}\Big[& 3e'\cos(n't-\omega') + 3\alpha^2e''\cos(n''t-\omega'') + \tfrac{3}{2}\alpha e'\cos(2n't-n''t-\omega') \\
& - \tfrac{3}{2}\alpha e'\cos(n''t-\omega') - \tfrac{3}{2}\alpha e''\cos(n't-\omega'') + \tfrac{3}{2}\alpha e''\cos(n't-2n''t+\omega'') - \tfrac{9}{4}(e'^2+\alpha^2e''^2) \\
& + \tfrac{3}{4}e'^2\cos 2(n't-\omega') + \tfrac{3}{4}\alpha^2e''^2\cos 2(n''t-\omega'') - \tfrac{3}{2}\alpha(e'^2+e''^2+\tfrac{1}{2}\gamma''^2)\cos(n't-n''t) \\
& + \tfrac{9}{8}\alpha e'^2\cos(3n't-n''t-2\omega') + \tfrac{3}{8}\alpha e'^2\cos(n't+n''t-2\omega') + \tfrac{3}{8}\alpha e''^2\cos(n't+n''t-2\omega'') \\
& + \tfrac{9}{8}\alpha e''^2\cos(n't-3n''t+2\omega'') - \tfrac{9}{4}\alpha e'e''\cos(2n't-\omega'-\omega'') - \tfrac{9}{4}\alpha e'e''\cos(2n''t-\omega'-\omega'') \\
& + \tfrac{3}{4}\alpha e'e''\cos(2n't-2n''t-\omega'+\omega'') + \tfrac{27}{4}\alpha e'e''\cos(\omega'-\omega'') + \tfrac{3}{4}\alpha\gamma''^2\cos(n't+n''t-2\Omega'')\Big] \\
+ \frac{1}{\Delta^4}\Big[& \tfrac{15}{8}\{2e'^2+5\alpha^2e'^2+5\alpha^2e''^2+2\alpha^4e''^2\} + \tfrac{15}{8}\{2-3\alpha^2\}e'^2\cos 2(n't-\omega') \\
& + \tfrac{15}{4}\alpha e'^2\cos(3n't-n''t-2\omega') - \tfrac{45}{4}\alpha e'^2\cos(n't+n''t-2\omega') - \tfrac{15}{2}\alpha\{e'^2+\alpha^2e''^2\}\cos(n't-n''t) \\
& - \tfrac{45}{8}\alpha^2\{e'^2+e''^2\}\cos 2(n't-n''t) - \tfrac{15}{8}\alpha\{3-\alpha^2\}e'e''\cos(2n't-\omega'-\omega'') - \tfrac{45}{4}\alpha\{1+\alpha^2\}e'e''\cos(\omega'-\omega'') \\
& + \tfrac{15}{4}\alpha\{1+\alpha^2\}e'e''\cos(2n't-2n''t-\omega''+\omega') + \tfrac{15}{4}\alpha\{1-3\alpha^2\}e'e''\cos(2n't-\omega'-\omega'') \\
& + \tfrac{105}{4}\alpha^2e'e''\cos(n't+n''t-\omega'-\omega'') - \tfrac{15}{4}\alpha^2e'e''\cos(n't-n''t-\omega'+\omega'') \\
& - \tfrac{45}{8}\alpha^2e'e''\cos(3n't-n''t-\omega'-\omega'') + \tfrac{15}{8}\alpha^2e'e''\cos(3n't-3n''t-\omega'+\omega'') \\
& + \tfrac{135}{8}\alpha^2e'e''\cos(n't-n''t+\omega'-\omega'') - \tfrac{45}{8}\alpha^2e'e''\cos(n't-3n''t+\omega'+\omega'') \\
& + \tfrac{15}{16}\alpha^2e'^2\cos(4n't-2n''t-2\omega') + \tfrac{135}{16}\alpha^2e'^2\cos 2(n''t-\omega') + \tfrac{135}{16}\alpha^2e''^2\cos 2(n't-\omega'') \\
& + \tfrac{15}{16}\alpha^2e''^2\cos(2n't-4n''t+2\omega'') - \tfrac{15}{8}\alpha^2\{3-2\alpha^2\}e''^2\cos 2(n''t-\omega'') \\
& - \tfrac{45}{4}\alpha^3e''^2\cos(n't+n''t-2\omega'') + \tfrac{15}{4}\alpha^3e''^2\cos(n't-3n''t+2\omega'')\Big]\Big\}
\end{aligned} \tag{13}$$

Equation (10) also gives, by neglecting the terms divided by $a'^5\Delta^9$ which are not needed in this investigation,

$$\begin{aligned}
\frac{1}{f^5} = \frac{1}{a'^5\Delta^5}\Big\{ 1 + \frac{1}{\Delta^2}\Big[& 5e'\cos(n't-\omega') + 5\alpha^2e''\cos(n''t-\omega'') + \tfrac{5}{2}\alpha e'\cos(2n't-n''t-\omega') \\
& - \tfrac{15}{2}\alpha e'\cos(n''t-\omega') - \tfrac{15}{2}\alpha e''\cos(n't-\omega'') + \tfrac{5}{2}\alpha e''\cos(n't-2n''t+\omega'') + \tfrac{15}{4}\{e'^2+\alpha^2e''^2\} \\
& + \tfrac{5}{4}e'^2\cos 2(n't-\omega') + \tfrac{5}{4}\alpha^2e''^2\cos 2(n''t-\omega'') - \tfrac{5}{2}\alpha\{e'^2+e''^2+\tfrac{1}{2}\gamma''^2\}\cos(n't-n''t) \\
& + \tfrac{15}{8}\alpha e'^2\cos(3n't-n''t-2\omega') + \tfrac{5}{8}\alpha e'^2\cos(n't+n''t-2\omega') + \tfrac{5}{8}\alpha e''^2\cos(n't+n''t-2\omega'') \\
& + \tfrac{15}{8}\alpha e''^2\cos(n't-3n''t+2\omega'') - \tfrac{15}{4}\alpha e'e''\cos(2n't-\omega'-\omega'') - \tfrac{15}{4}\alpha e'e''\cos(2n''t-\omega'-\omega'') \\
& + \tfrac{5}{4}\alpha e'e''\cos(2n't-2n''t-\omega'+\omega'') + \tfrac{45}{4}\alpha e'e''\cos(\omega'-\omega'') + \tfrac{5}{4}\alpha\gamma''^2\cos(n't+n''t-2\Omega'')\Big]\Big\}
\end{aligned} \tag{14}$$

If we now develop the value of Δ in the usual form we shall have

$$\left.\begin{aligned}
\frac{1}{\Delta^5} &= \tfrac{1}{2}b^{(0)}_{\frac{5}{2}} + b^{(1)}_{\frac{5}{2}}\cos(n't-n''t) + b^{(2)}_{\frac{5}{2}}\cos 2(n't-n''t) + \ldots + b^{(i)}_{\frac{5}{2}}\cos i(n't-n''t) \\
\frac{1}{\Delta^7} &= \tfrac{1}{2}b^{(0)}_{\frac{7}{2}} + b^{(1)}_{\frac{7}{2}}\cos(n't-n''t) + b^{(2)}_{\frac{7}{2}}\cos 2(n't-n''t) + \ldots + b^{(i)}_{\frac{7}{2}}\cos i(n't-n''t)
\end{aligned}\right\} \tag{15}$$

In the substitution of the value of f in equation (3) the only terms which give the argument of the required inequality, depend on Δ^{-5} and Δ^{-7}; and of these we need retain only those in which the algebraic sum of the coefficients of $n't$ and $n''t$ is equal to ± 2. Then the proper substitutions in equation (3) will give,

$$\begin{aligned}
R = \frac{m''r^2}{a'^3}\Big\{ & \Big[\tfrac{45}{32}\alpha b^{(17)}_{\frac{7}{2}} + \tfrac{15}{64}\{3\alpha^2-2\}b^{(18)}_{\frac{7}{2}} - \tfrac{15}{32}\alpha b^{(19)}_{\frac{7}{2}} - \tfrac{15}{128}\alpha^2 b^{(20)}_{\frac{7}{2}} \\
& - \tfrac{135}{128}\alpha^2 b^{(16)}_{\frac{7}{2}} - \tfrac{3}{32}b^{(18)}_{\frac{7}{2}} - \tfrac{9}{64}\alpha b^{(19)}_{\frac{7}{2}} - \tfrac{3}{64}\alpha b^{(17)}_{\frac{5}{2}}\Big] e'^2\cos(16n't-18n''t+2\omega') \\
& + \Big[\tfrac{45}{64}\alpha^2 b^{(15)}_{\frac{5}{2}} + \tfrac{45}{64}\alpha^2 b^{(19)}_{\frac{5}{2}} - \tfrac{105}{32}\alpha^2 b^{(17)}_{\frac{7}{2}} + \tfrac{15}{32}\alpha\{3\alpha^2-1\}b^{(16)}_{\frac{7}{2}} \\
& + \tfrac{15}{32}\alpha\{3-\alpha^2\}b^{(18)}_{\frac{7}{2}} + \tfrac{9}{32}\alpha b^{(18)}_{\frac{5}{2}} + \tfrac{9}{32}\alpha b^{(16)}_{\frac{5}{2}}\Big] e'e''\cos(16n't-18n''t+\omega'+\omega'') \\
& + \Big[\tfrac{15}{64}\alpha^2\{3-2\alpha^2\}b^{(16)}_{\frac{7}{2}} + \tfrac{45}{32}\alpha^3 b^{(17)}_{\frac{7}{2}} - \tfrac{15}{32}\alpha^3 b^{(15)}_{\frac{7}{2}} - \tfrac{15}{128}\alpha^2 b^{(14)}_{\frac{7}{2}} \\
& - \tfrac{135}{128}\alpha^2 b^{(18)}_{\frac{7}{2}} - \tfrac{3}{32}\alpha^2 b^{(16)}_{\frac{5}{2}} - \tfrac{3}{64}\alpha b^{(17)}_{\frac{5}{2}} - \tfrac{9}{64}\alpha b^{(15)}_{\frac{5}{2}}\Big] e''^2\cos(16n't-18n''t+2\omega'') \\
& + \Big[-\tfrac{3}{32}\alpha b^{(17)}_{\frac{5}{2}} - \tfrac{3}{16}\alpha^2 b^{(16)}_{\frac{5}{2}}\Big]\gamma''^2\cos(16n't-18n''t+2\Omega'')\Big\}
\end{aligned} \tag{16}$$

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shape that the different terms of any order may be readily compared with each other.

4. DELAUNAY's calculations show that the terms of the second order, with respect to the masses, are nearly insensible in comparison with those of the first order; and for this reason I have in this investigation restricted my calculations wholly to terms of the first order. The calculations are necessarily divided into two parts. In the first part, I have given the calculations requisite for determining the values of the forces arising from the attraction of the planet on the moon; and, in the second part, I have given the calculation of the effect of these forces on the motion of the moon. I have the satisfaction of finding a perfect agreement between my results and those of DELAUNAY in so far as the determination of the forces is concerned; but in the calculation of the effects of these forces on the moon's motion I have obtained a totally different value; inasmuch as I find the coefficient of the inequality to be only 0″.0192, whereas DELAUNAY has found 16″.02 for the coefficient, which is nearly *nine hundred times greater*. The cause of this discrepancy will be fully explained in the course of this investigation.

5. We shall now investigate the forces by which the planet acts upon the moon; and for this purpose we shall resume the consideration of equations (8) and (10) which we have given in No. 158 of this Journal, namely

$$(1)\quad f=\{r'^2+r''^2-2r'r''\cos\theta''\cos(v'-v'')\}^{\frac{1}{2}};$$

$$(2)\quad R=-\frac{m''}{f}-\frac{m''r^2}{4f^3}+\frac{3m''r^2\sin^2\theta}{4f^3}-\tfrac{3}{2}\frac{m''r^2}{f^5}\Big\{\tfrac{1}{4}r^2-\tfrac{1}{2}r''^2\cos^2\theta\sin^2\theta''-rr''\sin\theta\sin\theta''+\tfrac{1}{2}r''^2\cos^2\theta\cos^2\theta''\cos 2(v-v'')$$
$$+\cos\theta\{2r''^2\sin\theta\sin\theta''\cos\theta''-rr''\cos\theta''\}\cos(v-v'')+\tfrac{1}{2}r'^2\cos^2\theta\cos 2(v-v')$$
$$+\{rr'-2r'r''\sin\theta\sin\theta''\}\cos\theta\cos(v-v'')-r'r''\cos^2\theta\cos\theta''\cos(2v-v'-v'')\Big\}$$

In these equations m'' denotes the planet's mass, and f denotes its distance from the center of the earth; r, v and θ denote the moon's geocentric polar coordinates; and the same letters with one and two accents designate the heliocentric coordinates of the *earth* and *Venus* respectively. If we designate the mean longitudes of the *moon*, *earth* and *Venus* by nt $n't$ $n''t$ respectively, the argument of the proposed inequality must contain the terms $nt+16n't-18n''t$, together with one or more terms which are functions of the the perihelia and nodes of the different orbits. In this investigation we shall neglect the inclination of the moon's orbit to the ecliptic, which is taken as the fundamental plane; we shall also neglect the terms of the second order with respect to the disturbing masses, together with those which have the ratio of the moon's distance to that of the sun for a multiplier; and by this means the value of R will become

$$(3)\qquad R=-\frac{m''r^2}{4f^3}+\tfrac{3}{4}\frac{m''r^2}{f^3r''^2}\sin^2\theta''.$$

In order to develop this equation it is necessary to expand the value of f in the form of an infinite series of the multiples of the angle $v'-v''$. We may put the value of f under the following form:

$$f=r'\{1+\frac{r''^2}{r'^2}-2\frac{r''}{r'}\cos\theta''\cos(v'-v'')\}^{\frac{1}{2}}.\qquad(4)$$

This equation may be developed in terms of the variable ratio $\frac{r''}{r'}$ and the multiples of the true difference of longitudes v' and v''; and then corrections may be applied so as to take into account the ellipticities of the orbits. As this is the method of development employed by DELAUNAY, we shall, in order to be wholly independent of what has been published on the subject, proceed in an entirely different manner. The ecliptic being the fundamental plane, we shall put i'' for the inclination, and Ω'' for the longitude of the node, of the orbit of *Venus* on that plane. We shall retain in the calculations quantities of the order e'^2, $e'e''$, e''^2 and γ''^2, in which e' and e'' denote the eccentricities of the orbits of the *earth* and *Venus* respectively; and $\gamma''=\tan i''$. Then we shall have in terms of the mean motions

$$r'=a'\{1+\tfrac{1}{2}e'^2-e'\cos(n't-\omega')-\tfrac{1}{2}e'^2\cos 2(n't-\omega')\},\quad(5)$$
$$r''=a''\{1+\tfrac{1}{2}e''^2-e''\cos(n''t-\omega'')-\tfrac{1}{2}e''^2\cos 2(n''t-\omega'')\},\quad(6)$$
$$v'=n't+2e'\sin(n't-\omega')+\tfrac{5}{4}e'^2\sin 2(n't-\omega'),\qquad(7)$$

$$(8)\qquad v''=n''t+2e''\sin(n''t-\omega'')+\tfrac{5}{4}e''^2\sin 2(n''t-\omega'')-\tfrac{1}{4}\gamma''^2\sin 2(n''t-\Omega''),$$
$$(9)\quad \cos\theta''=1-\tfrac{1}{4}\gamma''^2+\tfrac{1}{4}\gamma''^2\cos 2(n''t-\Omega'').$$

If we substitute these values in equation (1) it will become

$$f^2=a'^2+a''^2-2a'a''\cos(n't-n''t)+a'^2\{\tfrac{3}{2}e'^2-2e'\cos(n't-\omega')-\tfrac{1}{2}e'^2\cos 2(n't-\omega')\}$$
$$+a''^2\{\tfrac{3}{2}e''^2-2e''\cos(n''t-\omega'')-\tfrac{1}{2}e''^2\cos 2(n''t-\omega'')\}$$
$$-2a'a''\Big\{\tfrac{1}{2}e'\cos(2n't-n''t-\omega')-\tfrac{3}{2}e'\cos(n''t-\omega')-\tfrac{3}{2}e''\cos(n't-\omega'')+\tfrac{1}{2}e''\cos(n't-2n''t+\omega'')$$
$$(10)\qquad -\tfrac{1}{2}\{e'^2+e''^2+\tfrac{1}{2}\gamma''^2\}\cos(n't-n''t)+\tfrac{3}{8}e'^2\cos(3n't-n''t-2\omega')+\tfrac{1}{8}e'^2\cos(n't+n''t-2\omega')$$
$$+\tfrac{1}{8}e''^2\cos(n't+n''t-2\omega'')+\tfrac{3}{8}e''^2\cos(n't-3n''t+2\omega'')-\tfrac{3}{4}e'e''\cos(2n't-\omega'-\omega'')$$
$$-\tfrac{3}{4}e'e''\cos(2n''t-\omega'-\omega'')+\tfrac{1}{4}e'e''\cos(2n't-2n''t-\omega'+\omega'')+\tfrac{9}{4}e'e''\cos(\omega'-\omega'')+\tfrac{1}{4}\gamma''^2\cos(n't+n''t-2\Omega'')\Big\}$$

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If we now put

$$\alpha=\frac{a''}{a'} \tag{11}$$

$$\Delta^2=1+\frac{a''^2}{a'^2}-2\frac{a''}{a'}\cos(n't-n''t)=1+\alpha^2-2\alpha\cos(n't-n''t), \tag{12}$$

equation (10) will give,

$$\begin{aligned}
\frac{1}{f^3}=\frac{1}{a'^3\Delta^3}\Big\{1+\frac{1}{\Delta^2}\Big[&3e'\cos(n't-\omega')+3\alpha^2e''\cos(n''t-\omega'')+\tfrac{3}{2}\alpha e'\cos(2n't-n''t-\omega')\\
&-\tfrac{9}{2}\alpha e'\cos(n''t-\omega')-\tfrac{9}{2}\alpha e''\cos(n't-\omega'')+\tfrac{3}{2}\alpha e''\cos(n't-2n''t+\omega'')-\tfrac{9}{4}(e'^2+\alpha^2e''^2)\\
&+\tfrac{3}{4}e'^2\cos 2(n't-\omega')+\tfrac{3}{4}\alpha^2e''^2\cos 2(n''t-\omega'')-\tfrac{3}{2}\alpha(e'^2+e''^2+\tfrac{1}{2}\gamma''^2)\cos(n't-n''t)\\
&+\tfrac{9}{8}\alpha e'^2\cos(3n't-n''t-2\omega')+\tfrac{3}{8}\alpha e'^2\cos(n't+n''t-2\omega')+\tfrac{3}{8}\alpha e''^2\cos(n't+n''t-2\omega'')\\
&+\tfrac{9}{8}\alpha e''^2\cos(n't-3n''t+2\omega'')-\tfrac{9}{4}\alpha e'e''\cos(2n't-\omega'-\omega'')-\tfrac{9}{4}\alpha e'e''\cos(2n''t-\omega'-\omega'')\\
&+\tfrac{3}{4}\alpha e'e''\cos(2n't-2n''t-\omega'+\omega'')+\tfrac{27}{4}\alpha e'e''\cos(\omega'-\omega'')+\tfrac{3}{4}\alpha\gamma''^2\cos(n't+n''t-2\Omega'')\Big]\\
+\frac{1}{\Delta^4}\Big[&\tfrac{15}{8}\{2e'^2+5\alpha^2e'^2+5\alpha^2e''^2+2\alpha^4e''^2\}+\tfrac{15}{8}\{2-3\alpha^2\}e'^2\cos 2(n't-\omega')\\
&+\tfrac{15}{4}\alpha e'^2\cos(3n't-n''t-2\omega')-\tfrac{45}{4}\alpha e'^2\cos(n't+n''t-2\omega')-\tfrac{15}{2}\alpha\{e'^2+\alpha^2e''^2\}\cos(n't-n''t)\\
&-\tfrac{45}{8}\alpha^2\{e'^2+e''^2\}\cos 2(n't-n''t)-\tfrac{15}{8}\alpha\{3-\alpha^2\}e'e''\cos(2n't-\omega'-\omega'')-\tfrac{45}{4}\alpha\{1+\alpha^2\}e'e''\cos(\omega'-\omega'')\\
&+\tfrac{15}{4}\alpha\{1+\alpha^2\}e'e''\cos(2n't-2n''t-\omega''+\omega')+\tfrac{15}{4}\alpha\{1-3\alpha^2\}e'e''\cos(2n't-\omega'-\omega'')\\
&+\tfrac{105}{4}\alpha^2e'e''\cos(n't+n''t-\omega'-\omega'')-\tfrac{15}{4}\alpha^2e'e''\cos(n't-n''t-\omega'+\omega'')\\
&-\tfrac{45}{8}\alpha^2e'e''\cos(3n't-n''t-\omega'-\omega'')+\tfrac{15}{8}\alpha^2e'e''\cos(3n't-3n''t-\omega'+\omega'')\\
&+\tfrac{135}{8}\alpha^2e'e''\cos(n't-n''t+\omega'-\omega'')-\tfrac{45}{8}\alpha^2e'e''\cos(n't-3n''t+\omega'+\omega'')\\
&+\tfrac{15}{16}\alpha^2e'^2\cos(4n't-2n''t-2\omega')+\tfrac{135}{16}\alpha^2e'^2\cos 2(n''t-\omega')+\tfrac{135}{16}\alpha^2e''^2\cos 2(n't-\omega'')\\
&+\tfrac{15}{16}\alpha^2e''^2\cos(2n't-4n''t+2\omega'')-\tfrac{15}{8}\alpha^2\{3-2\alpha^2\}e''^2\cos 2(n''t-\omega'')\\
&-\tfrac{45}{4}\alpha^3e''^2\cos(n't+n''t-2\omega'')+\tfrac{15}{4}\alpha^3e''^2\cos(n't-3n''t+2\omega'')\Big]\Big\}
\end{aligned} \tag{13}$$

Equation (10) also gives, by neglecting the terms divided by $a'^5\Delta^9$ which are not needed in this investigation,

$$\begin{aligned}
\frac{1}{f^5}=\frac{1}{a'^5\Delta^5}\Big\{1+\frac{1}{\Delta^2}\Big[&5e'\cos(n't-\omega')+5\alpha^2e''\cos(n''t-\omega'')+\tfrac{5}{2}\alpha e'\cos(2n't-n''t-\omega')\\
&-\tfrac{15}{2}\alpha e'\cos(n''t-\omega')-\tfrac{15}{2}\alpha e''\cos(n't-\omega'')+\tfrac{5}{2}\alpha e''\cos(n't-2n''t+\omega'')+\tfrac{15}{4}\{e'^2+\alpha^2e''^2\}\\
&+\tfrac{5}{4}e'^2\cos 2(n't-\omega')+\tfrac{5}{4}\alpha^2e''^2\cos 2(n''t-\omega'')-\tfrac{5}{2}\alpha\{e'^2+e''^2+\tfrac{1}{2}\gamma''^2\}\cos(n't-n''t)\\
&+\tfrac{15}{8}\alpha e'^2\cos(3n't-n''t-2\omega')+\tfrac{5}{8}\alpha e'^2\cos(n't+n''t-2\omega')+\tfrac{5}{8}\alpha e''^2\cos(n't+n''t-2\omega'')\\
&+\tfrac{15}{8}\alpha e''^2\cos(n't-3n''t+2\omega'')-\tfrac{15}{4}\alpha e'e''\cos(2n't-\omega'-\omega'')-\tfrac{15}{4}\alpha e'e''\cos(2n''t-\omega'-\omega'')\\
&+\tfrac{5}{4}\alpha e'e''\cos(2n't-2n''t-\omega'+\omega'')+\tfrac{45}{4}\alpha e'e''\cos(\omega'-\omega'')+\tfrac{5}{4}\alpha\gamma''^2\cos(n't+n''t-2\Omega'')\Big]\Big\}
\end{aligned} \tag{14}$$

If we now develop the value of Δ in the usual form we shall have

$$\left.\begin{aligned}
\frac{1}{\Delta^5}&=\tfrac{1}{2}b_{\frac{5}{2}}^{(0)}+b_{\frac{5}{2}}^{(1)}\cos(n't-n''t)+b_{\frac{5}{2}}^{(2)}\cos 2(n't-n''t)+\ldots+b_{\frac{5}{2}}^{(i)}\cos i(n't-n''t)\\
\frac{1}{\Delta^7}&=\tfrac{1}{2}b_{\frac{7}{2}}^{(0)}+b_{\frac{7}{2}}^{(1)}\cos(n't-n''t)+b_{\frac{7}{2}}^{(2)}\cos 2(n't-n''t)+\ldots+b_{\frac{7}{2}}^{(i)}\cos i(n't-n''t)
\end{aligned}\right\} \tag{15}$$

In the substitution of the value of f in equation (3) the only terms which give the argument of the required inequality, depend on Δ^{-5} and Δ^{-7}; and of these we need retain only those in which the algebraic sum of the coefficients of $n't$ and $n''t$ is equal to ± 2. Then the proper substitutions in equation (3) will give,

$$\begin{aligned}
R=\frac{m''r^2}{a'^3}\Big\{\Big[&\tfrac{45}{32}\alpha b_{\frac{7}{2}}^{(17)}+\tfrac{15}{64}\{3\alpha^2-2\}b_{\frac{7}{2}}^{(18)}-\tfrac{15}{32}\alpha b_{\frac{7}{2}}^{(19)}-\tfrac{15}{128}\alpha^2b_{\frac{7}{2}}^{(20)}\\
&-\tfrac{135}{128}\alpha^2b_{\frac{7}{2}}^{(16)}-\tfrac{3}{32}b_{\frac{7}{2}}^{(18)}-\tfrac{9}{64}\alpha b_{\frac{7}{2}}^{(19)}-\tfrac{3}{64}\alpha b_{\frac{5}{2}}^{(17)}\Big]e'^2\cos(16n't-18n''t+2\omega')\\
+\Big[&\tfrac{45}{64}\alpha^2b_{\frac{5}{2}}^{(15)}+\tfrac{45}{64}\alpha^2b_{\frac{5}{2}}^{(19)}-\tfrac{105}{32}\alpha^2b_{\frac{7}{2}}^{(17)}+\tfrac{15}{32}\alpha\{3\alpha^2-1\}b_{\frac{7}{2}}^{(16)}\\
&+\tfrac{15}{32}\alpha\{3-\alpha^2\}b_{\frac{7}{2}}^{(18)}+\tfrac{9}{32}\alpha b_{\frac{5}{2}}^{(18)}+\tfrac{9}{32}\alpha b_{\frac{5}{2}}^{(16)}\Big]e'e''\cos(16n't-18n''t+\omega'+\omega'')\\
+\Big[&\tfrac{15}{64}\alpha^2\{3-2\alpha^2\}b_{\frac{7}{2}}^{(16)}+\tfrac{45}{32}\alpha^3b_{\frac{7}{2}}^{(17)}-\tfrac{15}{32}\alpha^3b_{\frac{7}{2}}^{(15)}-\tfrac{15}{128}\alpha^2b_{\frac{7}{2}}^{(14)}\\
&-\tfrac{135}{128}\alpha^2b_{\frac{7}{2}}^{(18)}-\tfrac{3}{32}\alpha^2b_{\frac{5}{2}}^{(16)}-\tfrac{3}{64}\alpha b_{\frac{5}{2}}^{(17)}-\tfrac{9}{64}\alpha b_{\frac{5}{2}}^{(15)}\Big]e''^2\cos(16n't-18n''t+2\omega'')\\
+\Big[&-\tfrac{3}{32}\alpha b_{\frac{5}{2}}^{(17)}-\tfrac{3}{16}\alpha^2b_{\frac{5}{2}}^{(16)}\Big]\gamma''^2\cos(16n't-18n''t+2\Omega'')\Big\}
\end{aligned} \tag{16}$$

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Or in a more abridged form

$$R=\frac{mr}{a'^3}\Big\{A_1e'^2\cos(16n't-18n''t+2\omega')+A_2e'e''\cos(16n't-18n''t+\omega'+\omega'')$$
$$+A_3e''^2\cos(16n't-18n''t+2\omega'')+A_4\gamma''^2\cos(16n't-18n''t+2\Omega'')\Big\}\tag{17}$$

In order to reduce this equation to numbers we must know the values of α and the quantities $b_{\frac{5}{2}}^{(i)}$ and $b_{\frac{7}{2}}^{(i)}$ which are functions of α. The value of α is the ratio of the distances of *Venus* and the earth from the sun. Therefore $\alpha=0.7233323$, and the following values of $b_{\frac{5}{2}}^{(i)}$ and $b_{\frac{7}{2}}^{(i)}$ are taken from DELAUNAY's work already mentioned, with the exception of $b_{\frac{7}{2}}^{(14)}$ and $b_{\frac{7}{2}}^{(20)}$ which have been independently computed.

$$b_{\frac{5}{2}}^{(15)}=6.19409,\quad b_{\frac{5}{2}}^{(16)}=4.83623,\quad b_{\frac{5}{2}}^{(17)}=3.76216,\quad b_{\frac{5}{2}}^{(18)}=2.91686,\quad b_{\frac{5}{2}}^{(19)}=2.25459,\tag{18}$$

$$b_{\frac{7}{2}}^{(14)}=152.316,\quad b_{\frac{7}{2}}^{(15)}=124.329,\quad b_{\frac{7}{2}}^{(16)}=100.936,\quad b_{\frac{7}{2}}^{(17)}=81.539,\quad b_{\frac{7}{2}}^{(18)}=65.569,\quad b_{\frac{7}{2}}^{(19)}=52.505,$$
$$b_{\frac{7}{2}}^{(20)}=41.880.\tag{19}$$

The substitution of these quantities in equation (16) gives the following values:

$$A_1=-0.37285\ ,\quad A_2=+1.2052\ ,\quad A_3=-0.99672\ ,\quad A_4=-0.729564\,;\tag{20}$$

while DELAUNAY gives

$$A_1=-0.3732\ ,\quad A_2=+1.2055\ ,\quad A_3=-0.9965\ ,\quad A_4=-2.9183,\tag{21}$$

which are practically identical with the ones just found, if we remember that γ'' in this paper is equal to tan i'', while in DELAUNAY's work γ'' is equal to sin $\frac{1}{2}i''$, so that his value of A_4 ought to be four times the value required by my equations.

6. If we now take the differential coefficient of equation (17) with respect to r, we shall get after substituting

$$r=a\{1-e\cos(nt-\omega)\}.\tag{22}$$

$$\left(\frac{dR}{dr}\right)=\frac{m''a}{a'^3}\Big\{2A_1e'^2\cos(16n't-18n''t+2\omega')-A_1ee'^2\cos(nt+16n't-18n''t-\omega+2\omega')$$
$$+2A_2e'e''\cos(16n't-18n''t+\omega'+\omega'')-n''ee'e''\cos(nt+16n't-18n''t-\omega+\omega'+\omega'')$$
$$+2A_3e''^2\cos(16n't-18n''t+2\omega'')-A_3ee''^2\cos(nt+16n't-18n''t-\omega+2\omega'')$$
$$+2A_4\gamma''^2\cos(16n't-18n''t+2\Omega'')-A_4e\gamma''^2\cos(nt+16n't-18n''t-\omega+2\Omega'')\Big\}\tag{23}$$

(24) Now we have $\qquad n'=0.0748013n\ ,\quad n''=0.1215913n,$

Also at the epoch of 1800, we have

$$\left.\begin{array}{llll} e=0.05491\ , & e'=0.01679\ , & e''=0.00686\ , & i''=3^\circ\ 23'\ 30'' \\ & \omega'=99^\circ\ 30'\ 29''\ , & \omega''=128^\circ\ 43'\ 6''\ , & \Omega''=74^\circ\ 51'\ 41'' \end{array}\right\}\tag{25}$$

If we substitute these values in the formulas for the perturbations, which are given in article 7 of No. 158 of this Journal, we shall obtain for the perturbations in longitude, observing that $\left(\frac{dR}{dv}\right)=0$,

$$\left.\begin{array}{l}\delta v=+0''0007777\sin(nt+16n't-18n''t-\omega+2\omega')-0''.0010255\sin(nt+16n't-18n''t-\omega+\omega'+\omega'')\\ \quad+0''.0003460\sin(nt+16n't-18n''t-\omega+2\omega'')+0''.0190160\sin(nt+16n't-18n''t-\omega+2\Omega'')\end{array}\right\}\tag{26}$$

$$=-0''.01655\sin(nt+16n't-18n''t-\omega)+0''.00976\cos(nt+16n't-18n''t-\omega)\tag{27}$$

$$=+0''.01921\sin(nt+16n't-18n''t-\omega+149^\circ\ 28').\tag{28}$$

DELAUNAY gives for the perturbation of longitude arising from the same forces

(29) $\delta v=16''.024\sin(nt+16n't-18n''t-\omega+144^\circ\,39'.8)$

which is more than eight hundred times as great as in equation (28).

The value of δv in equation (28) is the whole perturbation of the moon's motion in longitude arising from the attraction of *Venus;* and were the moon's orbit wholly free from the disturbing influence of other forces, the period of the inequality would be 3341 days, or 9.1470 years. But by reason of the sun's attraction the perigee of the moon's orbit is in motion, and thus changes the period of the inequality from nine years to two hundred and seventy-three years.

7. We shall now show that the perturbation of the lunar orbit by the sun does not change the *amount* of perturbation produced by the planet, but only affects the *time* during which the perturbation takes place. In other words we shall show that the total amount of perturbation in the disturbed orbit is the same as it would have been in the undisturbed orbit. The truth of this statement will be evident from the following considerations:

First. The differential equations of motion do not con-

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tain the time t explicitly, but merely its differential dt. They therefore correspond to a *point*, rather than an *interval* of time. Now the fundamental conception in the theory of the variation of elements requires the elements to be constant during the time dt, although they may vary from one instant to another. The variation of the elements during the time dt are therefore infinitesimals of the second order in comparison with the variations of the coordinates, and *must* therefore be neglected. If we therefore integrate the differential equations of motion, supposing the elements of the disturbed orbit to be constant, and then suppose the elements to be variable in the integrals, we shall obtain the whole effect of the disturbing force. See *Mécanique Céleste*, Book II, Chapter VIII. We shall call this the *normal perturbation* due to the given disturbing force.

Second. The *whole disturbing force* is measured by the *coefficient* of the function which represents the force. Now this coefficient is independent of the constancy or variableness of the elements; and therefore the variation of the elements can only affect the rate of development of the force without changing its total amount. In the case under consideration the variation of the elements changes the time or period of the inequality from nine years to about two hundred and seventy years; and therefore the normal action of the force would produce as much disturbance in nine years as the disturbed action would in thirty times that period.

Third. We may represent the total force by the height of an inclined plane, and the length of the plane by the period of the argument. Now it is a fundamental law of motion on an inclined plane, that the *acceleration* depends only on the *height* of the plane, while the time of descent is proportional to its *length*. In the present case the normal length of the plane is nine years, while the disturbed length is two hundred and seventy years; but since the height is the same for both, it follows that the total normal acceleration would be the same as the disturbed acceleration, although the latter required a period thirty times as long. Now since the acceleration varies as the time and the space varies as the square of the time, it follows that DELAUNAY's value of the inequality is too large in the ratio of 273^2 to 9.1470^2; or as $891:1$. If we therefore diminish DELAUNAY's value of the inequality in the ratio of $891:1$, and increase it in the ratio of $408134:390000$, in order to correspond to the mass of *Venus* which we have employed in this investigation, we shall obtain $0''.0188$ for the coefficient of the inequality, which is practically identical with the value given by equation (28).

8. There is another inequality of long period arising from the action of *Venus*, whose normal period is the same as the one we have just computed. It is the union of three separate inequalities of the first order with respect to the eccentricities, each of which is of considerable magnitude; but they nearly destroy each other, the algebraic sum of them producing a single inequality of about double the magnitude of the one given by equation (28). They are derived from the following terms of R; namely,

$$R=\tfrac{3}{4}\,\frac{m''r^2}{f^5}\Big\{-r'^2\cos 2(v-v')-r''^2\cos 2(v-v'')+2r'r''\cos(2v-v'-v'')\Big\}, \tag{30}$$

This gives by taking the partial differential coefficients

$$\left(\frac{dR}{dr}\right)=\tfrac{3}{2}\,\frac{m''r}{f^5}\Big\{-r'^2\cos 2(v-v')-r''^2\cos 2(v-v'')+2r'r''\cos(2v-v'-v'')\Big\} \tag{31}$$

$$\left(\frac{dR}{dv}\right)=\tfrac{3}{2}\,\frac{m''r^2}{f^5}\Big\{r'^2\sin 2(v-v')+r''^2\sin 2(v-v'')-2r'r''\sin(2v-v'-v'')\Big\} \tag{32}$$

These become by neglecting the eccentricities of the orbits of the *earth* and *Venus*, and retaining only the useful terms,

$$\left(\frac{dR}{dr}\right)=\tfrac{3}{2}\,\frac{m''a}{f^5}\left\{\begin{aligned}&-a'^2\cos 2(nt-n't)+\tfrac{5}{2}a'^2 e\cos(nt-2n't+\omega)\\&-a''^2\cos 2(nt-n''t)+\tfrac{5}{2}a''^2 e\cos(nt-2n''t+\omega)\\&+2a'a''\cos(2nt-n't-n''t)-5a'a''e\cos(nt-n't-n''t+\omega)\end{aligned}\right\} \tag{33}$$

$$\left(\frac{dR}{dv}\right)=\tfrac{3}{2}\,\frac{m''a^2}{f^5}\left\{\begin{aligned}&a'^2\sin 2(nt-n't)-3a'^2e\sin(nt-2n't+\omega)\\&+a''^2\sin 2(nt-n''t)-3a''^2e\sin(nt-2n''t+\omega)\\&-2a'a''\sin(2nt-n't-n''t)+6a'a''e\sin(nt-n't-n''t+\omega)\end{aligned}\right\} \tag{34}$$

Now we have in the present case

$$\frac{1}{f^5}=\frac{1}{a'^5\Delta^5}\,; \tag{35}$$

and if the proper terms of equation (15) are substituted we shall find after putting, for abridgement,

$$\overline{m}^2=\tfrac{3}{2}\,\frac{m''a^3}{a'^3}\Big\{\tfrac{1}{2}\alpha^2 b_{\frac{5}{2}}^{(16)}+\tfrac{1}{2}b_{\frac{5}{2}}^{(18)}-\alpha b_{\frac{5}{2}}^{(17)}\Big\} \tag{36}$$

$$\left(\frac{dR}{dr}\right)=\frac{\overline{m}^2}{a^2}\Big\{-\cos(2nt+16n't-18n''t)+\tfrac{5}{2}e\cos(nt+16n't-18n''t+\omega)\Big\}\,; \tag{37}$$

$$\left(\frac{dR}{dv}\right)=\frac{\overline{m}^2}{a}\Big\{\sin(2nt+16n't-18n''t)-3e\sin(nt+16n't-18n''t+\omega)\Big\}. \tag{38}$$

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The substitution of these values of the forces in the formulas for the perturbations gives

$$\delta v = \frac{\overline{m}^2}{\mu} e(67928.8) \sin(nt+16n't-18n''t+\omega) \qquad (39)$$

If we reduce equation (36) to numbers we shall find, after multiplying by the radius in seconds

$$\frac{\overline{m}^2}{\mu} = 0''.000010375, \qquad (40)$$

Substituting this and the value of e, in equation (39), it becomes

$$\delta v = 0''.0387 \sin(nt+16n't-18n''t+\omega). \qquad (41)$$

The normal period of this inequality is 3341 days, the same as that of equation (28); but the motion of the perigee reduces the period to sixteen hundred and forty-three days, or four and one-half years, instead of increasing it to two hundred and seventy-three years as in the former case. This inequality is about double that given by equation (28); and yet it amounts to only about two hundred and thirty-six feet of arc on the moon's orbit; a space which the moon would pass over in one-fourteenth of a second of time. It is, however, much the largest inequality of long period arising from the action of *Venus*; and yet it is wholly insensible to the most refined observations. The action of the planets on the moon's motion would therefore seem to be of very little importance; and mathematicians and astronomers may very properly confine their researches in the lunar theory to the determination of the sun's action, since there is no reason to fear that their results will be sensibly modified by the action of foreign forces.

Cleveland, 1887 *September* 28.

ON THE TWO NEW ALGOL-TYPE VARIABLES,

7438 *Y CYGNI* AND *R CANIS MAJORIS*, 2610

By S. C. CHANDLER, Jr.

In announcing the variability of the first of these stars, on page 40 of this volume, it was stated that "I strongly surmised that the period will prove to be $1^d.4992$." This presumption, the reasons for which were given, was afterwards somewhat weakened by a single observation made under very difficult circumstances in strong morning twilight, but subsequent observations have fully justified the surmise in question; the period, according to my latest determination, being $1^d.497776 = 1^d\,11^h\,56^m\,48^s$, with a probable uncertainty of perhaps two seconds.

With regard to Mr. Sawyer's star in *Canis Major*, the fact was established by his observations that the period is certainly an aliquot part of eight days, probably $1^d\,3^h \pm$ (see page 119). My own observations at that time gave nothing more definite, consequently, after the heliacal rising of the star, the epoch of minima had to be located anew. As even under the most favorable circumstances only every seventh or eighth minimum falls at a practicable hour, as observations were in this case limited to a short interval in the morning, and clouds destroy many even of these rare chances, for a low southern star — the process of "fishing" for a minimum was discouraging, and unsuccessful until October; during which month three minima have been determined. By combination with the series in the spring, I find the period $1^d\,3^h\,15^m\,55^s$, which is estimated to be within a very few seconds of the truth.

The appended ephemerides of these stars may, therefore, be relied upon as possessing more than the needful accuracy to enable observers to prepare for the observation of minima for many months to come.

It is my intention to keep both stars on my observing list, and to give a complete discussion of them at the end of the season. The communication of further detail is therefore reserved, except the following statement of the elements of the light-variations, as nearly as I can now determine them.

Y Cygni: $20^h\,46^m\,16^s$, $+34°\,7'.0$ (1875)

1886 Dec. $9^d\,11^h\,14^s.5$ (Greenw. M.T.) $+1^d\,11^h\,56^m\,48^s$ E

	M
Brightness at maximum,	7.1
Brightness at minimum,	7.9
Duration of decrease,	4 hours.
Duration of increase,	4 hours.
Stationary maximum brilliancy,	28 hours.

The comparison-stars and provisional light-scale will be found on page 47 of this volume.

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MINIMA OF *Y* CYGNI.

Heliocentric Greenwich M.T.

E 256—293				E 294—331				E 332—369			
1887		h	m	1888		h	m	1888		h	m
Dec.	27	21	35.3	Feb.	22	19	33.7	Apr.	19	17	32.1
	29	9	32.1		24	7	30.5		21	5	28.9
1888	30	21	28.9		25	19	27.3		22	17	25.7
Jan.	1	9	25.7		27	7	24.1		24	5	22.5
	2	21	22.5		28	19	20.9		25	17	19.3
	4	9	19.3	Mar.	1	7	17.7		27	5	16.1
	5	21	16.1		2	19	14.5		28	17	12.9
	7	9	12.9		4	7	11.3		30	5	9.7
	8	21	9.7		5	19	8.1	May	1	17	6.5
	10	9	6.5		7	7	4.9		3	5	3.3
	11	21	3.3		8	19	1.7		4	17	0.1
	13	9	0.1		10	6	58.5		6	4	56.9
	14	20	56.9		11	18	55.3		7	16	53.7
	16	8	53.7		13	6	52.1		9	4	50.5
	17	20	50.5		14	18	48.9		10	16	47.3
	19	8	47.3		16	6	45.7		12	4	44.1
	20	20	44.1		17	18	42.5		13	16	40.9
	22	8	40.9		19	6	39.3		15	4	37.7
	23	20	37.7		20	18	36.1		16	16	34.5
	25	8	34.5		22	6	32.9		18	4	31.3
	26	20	31.3		23	18	29.7		19	16	28.1
	28	8	28.1		25	6	26.5		21	4	24.9
	29	20	24.9		26	18	23.3		22	16	21.7
	31	8	21.7		28	6	20.1		24	4	18.5
Feb.	1	20	18.5		29	18	16.9		25	16	15.3
	3	8	15.3		31	6	13.7		27	4	12.1
	4	20	12.1	Apr.	1	18	10.5		28	16	8.9
	6	8	8.9		3	6	7.3		30	4	5.7
	7	20	5.7		4	18	4.1		31	16	2.5
	9	8	2.5		6	6	0.9	June	2	3	59.3
	10	19	59.3		7	17	57.7		3	15	56.1
	12	7	56.1		9	5	54.5		5	3	52.9
	13	19	52.9		10	17	51.3		6	15	49.7
	15	7	49.7		12	5	48.1		8	3	46.5
	16	19	46.5		13	17	44.9		9	15	43.3
	18	7	43.3		15	5	41.7		11	3	40.1
	19	19	40.1		16	17	38.5		12	15	36.9
	21	7	36.9		18	5	35.3		14	3	33.7

R CANIS MAJORIS: $7^d\,13^m\,49^s$, $-16°\,9'.7$ (1875)

1887 Mar. $26^d\,14^h\,58^m.5$ (Greenw. M.T.) $+1^d\,3^h\,15^m\,55^s$ E

	M
Brightness at maximum,	5.9
Brightness at minimum,	6.7
Duration of decrease,	2½ hours.
Duration of increase,	2½ hours.
Stationary maximum brilliancy,	22 hours.

The comparison-stars and provisional light-scale are as follows:

			1875.0 α	1875.0 δ	Light Scale		Equiv. Mag.
			h m s	° ′			M
g	U.A. 165 Can. Maj.		7 19 1	—15 57.4	22.3	=	5.70
f	" 144	"	10 35	15 22.0	16.4		6.12
b	" 169	"	19 24	13 30.4	16.0		6.14
a	" 156	"	15 15	14 7.7	15.7		6.16
h	" 94 Puppis		23 41	14 44.0	13.5		6.30
d	" 168 Can. Maj.		19 20	18 46.1	10.1		6.56
c	" 152	"	13 33	19 3.1	8.1		6.70
e	" 153	"	13 43	—17 17.8	4.6	=	6.94

The values of the light-scale and their equivalent magnitudes are determined from all my observations to date.

By means of the near commensurability expressed in the relation 22 Periods = 25 days — $9^m.8$, I have given the ephemeris for *R Canis Majoris* a very compact form; in an analogous way to that heretofore adopted for *U Ophiuchi*. The exact Greenwich M.T. of minimum for any date in the table is found by applying to the time in the right hand column the correction at the foot of the column. The numbers at the head of each column indicate the numbering of the epochs.

MINIMA OF *R* CANIS MAJORIS.

Heliocentric Greenwich M.T.

225 to 246	247 to 268	269 to 290	291 to 312	313 to 334	335 to 356	Greenw. M.T.
	1888					h m
Dec. 7	Jan. 1	Jan. 26	Feb. 20	Mar. 16	Apr. 10	5 20.1
8	2	27	21	17	11	8 36.0
9	3	28	22	18	12	11 51.9
10	4	29	23	19	13	15 7.8
11	5	30	24	20	14	18 23.7
12	6	31	25	21	15	21 39.6
14	8	Feb. 2	27	23	17	0 55.6
15	9	3	28	24	18	4 11.5
16	10	4	29	25	19	7 27.4
17	11	5	Mar. 1	26	20	10 43.3
18	12	6	2	27	21	13 59.2
19	13	7	3	28	22	17 15.1
20	14	8	4	29	23	20 31.0
21	15	9	5	30	24	23 47.0
23	17	11	7	Apr. 1	26	3 2.9
24	18	12	8	2	27	6 18.8
25	19	13	9	3	28	9 34.7
26	20	14	10	4	29	12 50.6
27	21	15	11	5	30	16 6.6
28	22	16	12	6	May 1	19 22.5
29	23	17	13	7	2	22 38.4
31	25	19	15	9	4	1 54.3
m +19.6	m +9.8	m 0.0	m —9.8	m —19.6	m —29.2	

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RING-MICROMETER OBSERVATIONS OF COMET *e* 1887,

MADE WITH A CLACEY $6\frac{1}{4}$-INCH REFRACTOR,

BY S. C. CHANDLER, JR.

1887 Cambridge M.T.	✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			m s	′ ″	h m s	° ′ ″		
May 30 10 33 53 (h m s)	1	4	+1 10.70	+ 3 19.4	15 43 20.62	—18 48 41.3	*n*8.845	0.887
30 10 59 43	2	4	+2 51.27	— 0 53.7	15 43 22.16	—18 47 43.5	*n*8.322	0.888
30 11 10 46	3	2	—1 46.06	—11 43.6	15 43 23.46	—18 47 27.3		0.882
July 12 9 27 58	4	10	+1 5.78	— 0 26.8	17 17 56.33	+ 6 45 58.1	*n*8.716	0.710
12 10 6 14	5	10	—2 3.37	+ 0 21.8	17 18 0.89	+ 6 46 22.0	8.341	0.718

Mean Places for 1887.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 42 7.82	+2.10	—18 52 0.6	— 0.1	Oe. Argel. 14900
2	15 40 28.79	+2.10	—18 46 49.7	— 0.1	Oe. Argel. 14867, 8
3	15 45 7.42	+2.10	—18 35 43.6	— 0.1	Oe. Argel. 14951
4	17 16 48.44	+2.11	+ 6 46 14.8	+10.1	BB. VI. +6° 3403
5	17 20 2.15	+2.11	+ 6 45 50.1	+10.1	BB. VI. +6° 3413

FILAR-MICROMETER OBSERVATIONS OF COMET 1887 *f* (*Olbers*),

MADE AT THE DUDLEY OBSERVATORY,

BY H. V. EGBERT.

1887 Albany M.T.	✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			m s	′ ″	h m s	° ′ ″		
Sept. 15 16 7 23 (h m s)	1	14	+0 29.70	—0 39.3	10 11 44.12	+30 0 30.6	*n*9.698	0.741
Nov. 1 17 33 7	2	5	—1 58.37	—0 40.1	13 49 21.54	+17 33 56.3	*n*9.655	0.735

Mean Places for 1887.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	10 11 14.37	+0.05	+30 1 17.3	—7.4	Leiden Zones 37, 68–39, 68
2	13 51 19.75	+0.16	+17 34 38.7	—2.3	W.B. 1088 (Lal. 25649)

CORRIGENDA.

No. 162 p. 141. Col. 1, line 8, the numerator should be $y'z-yz'$.

line 35. Second equation should be $\dfrac{N-\nu N''}{\alpha_0}=l$.

p. 143. First column of table, last line, for 0.000 put 0.009.

Recapitulation, line 10, for e put e'.

line 12, for ψ put ψ''.

line 18, for $L-L$ put $L''-L$.

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THE

ASTRONOMICAL JOURNAL.

No. 164.

VOL. VII. BOSTON, 1887 DECEMBER 14. NO. 20.

ON A METHOD OF COMPUTING AN ORBIT FROM THREE OBSERVATIONS,

BY REV. GEORGE M. SEARLE.

(Continued from No. 162.)

In any method of computing an orbit, the approximation may easily be carried far beyond the accuracy of the observations on which the computation is based, and thus much time wasted.

To see how far it is worth while to continue the approximation, it may be well to have some method of comparing the middle place which would be computed from the elements resulting from any hypothesis, with observation, without actually computing those elements and the middle place from them.

To do this, we may first compute the values of f, f'', and r', which would result for the time t' from the elements.

In order to this, we will first take the trigonometrical formula, true for any values of A and B,

$$\sin^2(A+B) = \sin^2 A + \sin^2 B + 2 \sin A \sin B \cos(A+B)$$

In this, making $g = A$, $g'' = B$, $g' = A+B$, we have putting for $\sin g$ the value $\frac{\sqrt{r'r''}\sin f}{b}$ and similarly for g' and g'', and multiplying by $\frac{b^2}{rr'r''}$, the equation

$$\frac{\sin^2 f'}{r'} = \frac{\sin^2 f}{r} + \frac{\sin^2 f''}{r''} + 2\frac{\sin f}{\sqrt{r}} \cdot \frac{\sin f''}{\sqrt{r''}} \cos g'$$

or making $\sigma = \frac{\sin f}{\sqrt{r}}$ and similarly σ' and σ''

$$\sigma'^2 = \sigma^2 + \sigma''^2 + 2\sigma\sigma'' \cos g'$$

It may be here remarked, that by obtaining the value of $\cos g'$ from this equation, and putting

$$b^{-2} = \frac{(1+\cos g')(1-\cos g')}{rr'' \sin^2 f'}$$

we can deduce the expression used in this method to obtain b^{-2}.

Having then obtained σ' from the values of σ, σ'', and g' $\left[= \frac{\epsilon-\delta}{2}\right]$ furnished by the hypothesis, $\frac{\sin^2 f'}{\sigma'^2}$ will denote the radius vector of the orbit where it cuts the r' which has been computed; or in other words the radius vector corresponding to f and f'' in the orbit. We will denote this by r'_0.

Now obviously

$$\sin g = \frac{\sigma}{\sigma'} \sin g'; \quad \text{and } \sin g'' = \frac{\sigma''}{\sigma'} \sin g',$$

g and g'' answering to f and f'' in the orbit; and by these and the value of p which we have from the hypothesis [which can also be computed by the formula $p = \frac{rr'' \sin^2 f'}{a \sin^2 g'}$ if g' has been obtained by the trial with sufficient accuracy] and the value of r'_0 just deduced, we shall have the values of η and η'' strictly corresponding with f and f'' in the orbit resulting from the hypothesis; and hence t'_0, the time at which a heavenly body moving in this orbit would cross r', by the formula

$$t'_0 = t + \frac{t''-t}{1+\frac{\eta}{\eta''}},$$

Let us denote $t'-t'_0$ by dt. We have then for ds, the distance traversed by the body in the time dt, the expression,

$$k\sqrt{\frac{2}{r'} - \frac{1}{a}}\, dt$$

Let us also denote $r'_0 - r'$ by dr'.

Now the angular divergence of the computed place from the observed, which latter corresponds to the end of r', will evidently be the resultant of dr' and ds, projected on a plane perpendicular to Δ' the line joining the earth and the heavenly body, and divided by Δ'. The square of this projection is equal to the square of the whole resultant minus the square of its projection on Δ'.

Now the projection of dr' on $\Delta' = dr' \cos z$, if by z we denote the angle formed at the body between r' and Δ'. The projection of ds on Δ' is the increase of Δ' in dt, minus the increase of Δ' produced by the motion of the earth in dt. This latter is approximately equal to $k \cos\beta' \sin(\lambda'-L')\, dt$, since the earth is moving toward $L'-90$ with a velocity of k,

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3	15 45 7.42	+2.10	—18 35 43.6	— 0.1	Oe. Argel. 14931
4	17 16 48.44	+2.11	+ 6 46 14.8	+10.1	BB. VI. +6° 3403
5	17 20 2.15	+2.11	+ 6 45 50.1	+10.1	BB. VI. +6° 3413

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			m s	′ ″	h m s	° ′ ″		
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To see how far it is worth while to continue the approximation, it may be well to have some method of comparing the middle place which would be computed from the elements resulting from any hypothesis, with observation, without actually computing those elements and the middle place from them.

To do this, we may first compute the values of f, f'', and r', which would result for the time t' from the elements.

In order to this, we will first take the trigonometrical formula, true for any values of A and B,

$$\sin^2(A+B) = \sin^2 A + \sin^2 B + 2 \sin A \sin B \cos(A+B)$$

In this, making $g = A$, $g'' = B$, $g' = A+B$, we have putting for $\sin g$ the value $\frac{\sqrt{r'r''} \sin f}{b}$ and similarly for g' and g'', and multiplying by $\frac{b^2}{rr'r''}$, the equation

$$\frac{\sin^2 f'}{r'} = \frac{\sin^2 f}{r} + \frac{\sin^2 f''}{r''} + 2 \frac{\sin f}{\sqrt{r}} \cdot \frac{\sin f''}{\sqrt{r''}} \cos g'$$

[illegible] making σ [illegible] and similarly σ' and σ''

[illegible] $\sigma''^2 + 2\sigma\sigma'' \cos g'$

[illegible] may be [illegible] from [illegible] that by obtaining the value of [illegible] putting

[illegible] $(1 - \cos g')$ [illegible] $\sin^2 f'$

[illegible] dedu[illegible] [illegible] in this method [illegible]

[illegible] ines of r, r', [illegible] r'' [illegible] will denote the [illegible] which has been computed; or in other words the radius vector corresponding to f and f'' in the orbit. We will denote this by r'_0.

Now obviously

$$\sin g = \frac{\sigma}{\sigma'} \sin g'; \text{ and } \sin g'' = \frac{\sigma''}{\sigma'} \sin g'.$$

g and g'' answering to f and f'' in the orbit [illegible] and by these and the value of p which we have from the [illegible] which can also be computed by the formula $p =$ [illegible] obtained by the trial with sufficient accuracy [illegible] has been r'_0 just deduced, we shall have the values of r and [illegible] corresponding with f and [illegible] hypothesis: and hence [illegible] in the moving in this orbit would [illegible]

[illegible]

Let us denote [illegible]. We have [illegible] tance traversed [illegible]

[illegible]

Let us also denote [illegible]

Now the angular [illegible]

[illegible]

Now the [illegible] denote the [illegible]

[illegible]

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and the cosine of the angle its line of motion forms with the line leading away from the body is $\cos\beta'\cos[\lambda'-180°-(L'-90°)]$. Hence the whole projection on Δ' of dr' and ds, which we will denote by $d\Delta'$, is equal approximately to

$$\left[\frac{\Delta''-\Delta}{t''-t}-k\cos\beta'\sin(\lambda'-L')\right]dt+dr'\cdot\cos z$$

The square of the whole resultant is equal to $(dr')^2+(ds)^2-2dr'\cdot ds\cdot\cos\gamma$ in which γ is the angle formed by r' with ds. We have then finally

$$[d\lambda'\cos\beta']^2+[d\beta']^2=\frac{[dr']^2+[ds]^2-2dr'\cdot ds\cdot\cos\gamma-[d\Delta']^2}{\Delta'^2}$$

in which γ is obtained by the formula

$$\sin\gamma=\frac{r'dv'}{ds}=\frac{k\sqrt{p}}{r'}\,\frac{dt}{ds},$$

and $\gamma>90$ when r' is increasing.

For z we have $\cos\psi'=\cos\beta'\cos(\lambda'-L')$, $\sin z=\dfrac{R'\sin\psi'}{r'}$. $z>90$ when $R'\cos\psi'>\Delta'$.

Condensation of the above Formulas.

Compute $\sigma=\dfrac{\sin f}{\sqrt{r}}\qquad\sigma''=\dfrac{\sin f''}{\sqrt{r}}$

$$\sigma'^2=\sigma^2+\sigma''^2+2\sigma\sigma''\cos g'\quad\text{or}=(\sigma+\sigma'')^2-4\sigma\sigma''\sin^2\tfrac{1}{2}g'$$

in which $g'=\dfrac{\varepsilon-\delta}{2}$ of the hypothesis, or zero for the parabola.

Then $r'_0=\dfrac{\sin^2 f'}{\sigma'^2}$; $\sin g=\dfrac{\sigma}{\sigma'}\sin g'$; $\sin g''=\dfrac{\sigma''}{\sigma'}\sin g'$

$$\eta=1+\frac{2\sqrt{r'_0}}{3p}w\sqrt{r''}\sin f\tan f$$

$$\eta''=1+\frac{2\sqrt{r'_0}}{3p}w''\sqrt{r}\sin f''\tan f''$$

$$\frac{\eta}{\eta''}\nu=\tau;\qquad dt=\frac{\tau(t'-t)-(t''-t')}{1+\tau}$$

$$ds=k\sqrt{\frac{2}{r'}-\frac{1}{a}}\,dt;\ dr'=r'_0-r'$$

$$\cos\psi'=\cos\beta'\cos(\lambda'-L');\ \sin z=\frac{R'\sin\psi'}{r'};$$

$$z>90\text{ when }R'\cos\psi'>\Delta'$$

$\sin\gamma=\dfrac{k\sqrt{p}}{r'}\cdot\dfrac{dt}{ds}$; $\qquad\gamma>90$ when r' is increasing

$$d\Delta'=\left[\frac{\Delta''-\Delta}{t''-t}-k\cos\beta'\sin(\lambda'-L')\right]dt+\cos z\cdot dr'$$

$$[d\lambda'\cos\beta']^2+[d\beta']^2=\frac{(dr')^2+(ds)^2-2dr'\cdot ds\cdot\cos\gamma-(d\Delta')^2}{\Delta'^2}$$

In these formulas, z, γ, $\dfrac{ds}{dt}$, $\dfrac{d\Delta'}{dt}$, will not vary, at least materially, from one hypothesis to another. Δ' may be obtained with sufficient accuracy by interpolating between Δ and Δ'', or by $\Delta'=\dfrac{r'\sin(\psi'+z)}{\sin\psi'}$.

The greater part of this computation may, owing to the smallness of the quantities, be made with *four, or even three,* places of logarithms.

It will perhaps be well to compute b^{-2} for the next hypothesis by putting

$$\sigma'=\frac{\sin f'}{\sqrt{r'}}\qquad s=\frac{\sin f}{\sigma'\sqrt{r}}\qquad s''=\frac{\sin f''}{\sigma'\sqrt{r''}}$$

$$4\sin^2\tfrac{1}{2}g'=\frac{(s+s''+1)(s+s''-1)}{ss''};\quad b^{-2}=\frac{4\sin^2\frac{1}{2}g'}{rr''\sin^2 f'}\cos^2\tfrac{1}{2}g'$$

We shall then have

$$dr'=4\,ss''\cdot r'_0\sin\tfrac{1}{2}(g'_0+g')\sin\tfrac{1}{2}(g'_0-g')$$

in which $g'_0=\dfrac{\varepsilon-\delta}{2}$ of the hypothesis. For r'_0 we may write r' with sufficient accuracy. We then have $r'_0=r'+dr'$

$$\sin g=s\sqrt{\frac{r'_0}{r'}}\sin g'_0\qquad\sin g''=s''\sqrt{\frac{r'_0}{r'}}\sin g'_0$$

$g+g''$ should be equal to g'_0

Then taking out w and w'' for g and g'', and computing p either by η' and

$$\sqrt{p}=\frac{\eta' rr''\sin 2f'}{k(t''-t)}\quad\text{or}\quad\text{by }p=\frac{rr''\sin^2 f'}{a\sin^2 g'_0}$$

in which, of course, a is the value used for the hypothesis, we have η and η'' by the formulas above and $\nu=\dfrac{\eta''}{\eta}\dfrac{(t''-t')}{(t'-t)}$ for the next hypothesis.

For computing the middle place, as we may wish to do it more than once, it may be as well to obtain z and γ, roughly once for all, also

$$\frac{ds}{dt}=k\sqrt{\frac{2}{r'}-\frac{1}{a}};\qquad\frac{d\Delta'}{dt}=\frac{\Delta''-\Delta}{t''-t}-k\cos\beta'\sin(\lambda'-L'),$$

to which last, if we wish to take account of second differences, we may add the term $+\dfrac{2e^2}{(t'-t)(t''-t')}\left[\dfrac{\Delta''-\Delta}{t''-t}-\dfrac{f}{e}\right]$ in which $e=t'-\frac{1}{2}(t+t'')$ and $f=\Delta'-\frac{1}{2}(\Delta+\Delta'')$.

We then shall have, making

$$m=\left(\frac{ds}{dt}\right)^2-\left(\frac{d\Delta'}{dt}\right)^2,\quad\text{and }n=2\left[\frac{ds}{dt}\cos\gamma+\frac{d\Delta'}{dt}\cos z\right],$$

$$(d\lambda'\cos\beta')^2+(d\beta')^2=\frac{\sin^2 z\cdot(dr')^2+m(dt)^2-ndr'\cdot dt}{\Delta'^2}$$

in which dr' is to be computed for each hypothesis by the formula above, and dt by $dt=\dfrac{\tau(t'-t)-(t''-t)}{1+\tau}$; the rest of the second member being nearly constant.

It is evident that if we are already possessed of even a rough ephemeris giving Δ', the values of Δ' and $\dfrac{d\Delta'}{dt}$ may be more easily obtained, taking care of course to correct the latter for the motion of the earth by the term $k\cos\beta'\sin(\lambda'-L')$, in which if greater accuracy is desired, we may multiply k by $\sqrt{\dfrac{2}{R'}-1}$ and increase $\lambda'-L'$ by $\tan^{-1}\dfrac{dR'}{R'dL'}=\tan^{-1}2.303\,\dfrac{d\log R'}{dL'}$. This angle is always less than one degree, but can be easily obtained from the almanac.

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The following elements were computed by this process for the Olbers comet from normal places for August 28 and September 21, together with an observation on October 19, kindly furnished by Mr. WENDELL of Harvard College Observatory, by permission of Prof. PICKERING:

$$\begin{aligned} T &= \text{Oct. } 8.4584 \text{ G.M.T.} \\ \Omega &= 84^\circ\ 29'\ 18''.4 \\ i &= 44\ \ 33\ \ 57\ .4 \\ \omega &= 65\ \ 19\ \ 25\ .6 \end{aligned} \left.\vphantom{\begin{aligned}\Omega\\i\\\omega\end{aligned}}\right\} 1887.0$$

$$\begin{aligned} \log e &= 9.968896 \\ \log a &= 1.239284 \\ \text{Period} &= 72.26 \text{ years.} \end{aligned}$$

The last hypothesis but one, corresponding to a period of 74.7 years, gave a discordance for the middle place, according to the formulas just given, of only $2''.2$; it might therefore well be doubted whether it would be worth while to make another, had the orbit been quite unknown, especially as the third place depended on a single observation.

The coefficients of $(dr')^2$, $(dt)^2$, and $dr'\cdot dt$, are of course conveniently multiplied by $(206265)^2$ in order that the discordance may be expressed in seconds of arc.

OBSERVATIONS OF VARIABLE STARS IN 1886—(*Continued*),

BY EDWIN F. SAWYER.

1. *R Coronae.*

This star was under observation from March 4 to November 14, 27 observations being obtained. The observed fluctuations of light were very small, not over 2 or 3 steps. *R* was brightest during August, when it was 5+ steps > DM. 30°,2682, and only 2 steps < DM. 32°,2621, or about $6^{M}.2$.

2. *S Coronae.*

Only 11 observations were obtained on this star, extending from March 28 to July 19. When first seen on March 28, *S* was 5+ steps < DM. 32°,2577, or about $8^{M}.6$. The increase of light was rather rapid, and a maximum was passed on May 10. The maximum brightness 5+ steps > DM. 32°,2575, and = DM. 32°,2578, or $7^{M}.6$, this representing rather a faint maximum. The light remained apparently constant from April 21 to June 4, or 44 days. The decrease of light was slow, and when last observed, on July 19, *S* was 5 steps < DM. 32°,2575, or about $8^{M}.6$.

3. *V Cancri.*

This star was observed on 11 evenings, from February 28 to April 29. When first seen on February 28, *V* was 5+ steps < DM. 18°,1923 and = DM. 18°,1917, or $8^{M}.7$. The increase of light was quite rapid, a maximum being passed on March 29. Maximum brightness = DM. 18°,1931, or about $7^{M}.7$. When last observed, on April 29, it was 2 steps > DM. 18°,1923, and 5 steps < DM. 18°,1931, or $8^{M}.1$.

4. *R Scuti.*

A good series of observations, 38 in number, was obtained on this star, extending from June 4 to December 14. These observations when charted exhibited only one maximum and two minima. The first minimum was passed on July 21, and was a bright one; light = 7.4 of my scale. The second minimum was a faint one, and was reached on December 2; light = 0.0. The interval between the two minima = 134 days. The only maximum observed was passed on September 12, and was rather a faint one; light = 17.2. The light at maximum remained nearly constant from August 5 to October 20, a period of 76 days.

5. *o Ceti.*

A good series of observations, 41 in number, was obtained on this star, extending from 1885 October 10 to 1886 March 7. The increase of light was rapid, and a maximum was reached on January 9. Maximum brightness, 5 steps > 237 (*U.A.*) *Ceti*, and 3 steps < 270 (*U.A.*) *Ceti*, or $5^{M}.4$; this representing a faint maximum. The light remained apparently constant for the 35 days from 1885 December 28 to 1886 February 1. The decrease of light was quite rapid after February 1.

6. *36 (U.A.) Ceti.*

19 observations were obtained on this star, extending from September 29 to 1887 January 27. When first seen it was 1 step > 28 (*U.A.*) *Ceti*, and 4 steps < 10 (*U.A.*) *Ceti*, or $6^{M}.6$. The increase of light from September 29 to October 23 was rapid. The light remained apparently constant from October 24 to November 14, when a further increase occurred. A maximum was reached on December 6; maximum brightness 5 steps > 7 (*U.A.*) *Ceti*, and 1 step < 18 (*U.A.*) *Ceti*, or $5^{M}.4$. The light remained at a standstill from November 19 to December 25, or 36 days. The decrease of light was also rapid, and when last observed, the star was 2 steps > 28 (*U.A.*) *Ceti*, and 5 steps < 7 (*U.A.*) *Ceti*, or $6^{M}.4$.

7. *W Cygni* (GORE 1885).

$21^{h}\ 30^{m}\ 33^{s}.9$, $+44^\circ\ 43'.7$ (1855.0).

This star was under observation from 1886 May 1 to 1887 February 20, 43 observations being obtained. These observations when charted exhibit one well determined maxi-

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mum and two minima. The first minimum occurred on July 8, the minimum brightness being 1 step > DM. 43°,4002, and 4 steps < DM. 44°,3889, or $6^{M}.7$. The second minimum, of the same brightness, was passed on November 5, the interval between the two minima being 120 days. The maximum occurred on September 10, when the brightness was 2 steps > DM. 44°,3889, and 4 steps < DM. 46°,3305, or $6^{M}.3$. A maximum also occurred about May 14 (increase of light not well observed), and the star was again apparently at maximum when the observations terminated.

8. *ρ Persei.* 1172

The observations on this star were continued (from the series published in No. 151 of this Journal, and extending from January 1) until April 22, and also from October 2 to December 24, 18 observations. The light remained nearly constant until November 4, when it decreased 4 or 5 steps, and so remained until December 21. The minimum occurred about November 24.

9. *R Virginis.* 4521

This star was observed on 12 evenings, from March 6 to April 29. When first seen, *R* was 5+ steps < DM. 8°,2626, or about $9^{M}.0$. The increase of light was rapid and uniform, a maximum being passed on April 8. Maximum brightness 3 steps > DM. 8°,2634, and 4 steps < combined light of DM. 8°,2620, 21, or about $8^{M}.0$; this representing a faint maximum. When last observed, *R* was = DM. 8°,2634, and 3 steps > DM. 8°,2626, or $8^{M}.2$.

10. *g Herculis.* 5912

The observations on this star extended from March 28 to November 27, and are 25 in number. The charted observations exhibit but one maximum and one minimum. The minimum occurred on June 14, and was a faint one. The maximum was passed about September 20. The light remained nearly constant from July 19 to November 4, a period of 108 days.

11. *R Ursae Majoris.*

8 scattering observations were obtained on this star, extending from March 24 to June 4. When first seen, *R* was 5+ steps < DM. 70,622, or about $8^{M}.8$. The increase of light appeared quite rapid, and a maximum was passed about April 29. When last observed, on June 4, *R* was = DM. 69°,584, and 3 steps < DM. 69°,579. or $8^{M}.2$.

Cambridgeport, 1887 *September* 13.

ON THE STRUCTURE OF *13 M HERCULIS*,

By Prof. MARK W. HARRINGTON.

The great cluster in *Hercules* has been frequently figured and always, with one exception, as a globular mass of stars much condensed in the center. Lord Rosse's observers alone found it crossed by three dark rifts, as shown in Figure 1, which is a copy of their drawing, the position only being changed in order to bring the notable hook above.

Fig. 1. The Great Cluster as seen in Lord Rosse's Reflecting Telescope — the Hook above.

Last spring I spent some time in studying this cluster with the aid of Mr. H. C. Markham, an artist whose sight I have found to be remarkably keen. We very soon found that under favorable circumstances, and with high powers, we were able to see the rifts which had been figured by Lord Rosse, and this was done before Mr. Markham knew of Lord Rosse's drawing. The rifts were somewhat difficult objects, but with proper precautions, they were frequently seen by Mr. Markham and myself, and also by Assistant Schaeberle. After following them for about a month the drawing, Figure 2, was made. I could not, however, make any measurements, as after illumination of the wires of my micrometer, I could not see the rifts.

The rifts were seen with both the 6-inch and 12-inch equatorials. They came out more and more plainly with increase of magnifying power, until 500 or 600 was reached. With higher powers the rifts seemed to increase and spread, and the cluster broke up into small clusters and scattered stars.

The resemblance of Figure 2 to Figure 1 is unmistakable. Taking the hook above as a starting point we have the three canals radiating in the one case as in the other.

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The absence of the brighter outlying stars in Figure 2 is without significance, as no attempt was made to include them. Aside from that, while the general resemblance between the two figures is notable, the differences in detail are remarkable. The upper or south rift is much broader and shorter in the later figure. The preceding rift is the best marked, and is much alike in the two drawings. The north or lower rift is much less marked, and is decidedly shorter in the later figure. In Lord ROSSE's drawing the radiating point of the rifts is nearly central; in Mr. MARKHAM's it is shifted backwards. In the first the central condensation is not marked; in the second it is preceding and slightly below the radiating point. I may say that the drawing was made before we permitted ourselves to refer to Lord ROSSE's drawing. As to the significance of these rifts I can not make any suggestion. They are so elusive that I sometimes almost doubted their existence, but I found that with patience I could always see them; and when after the completion of our drawing we finally compared it with Lord ROSSE's, we could no longer doubt that we had seen what had been seen by his observers. Whatever the rifts are, it seems certain that they have shifted their position slightly in the fifty or more years which have elapsed since the first drawing was made.

FIG. 2. THE GREAT CLUSTER WITH A POWER OF 500 OR 600, ANN ARBOR.

H. MARKHAM. April 13, 1887. 11 P.M.

Observatory, Ann Arbor, 1887 *August* 29.

NOTE ON THE DETERMINATION OF THE CONSTANT OF ABERRATION,

BY PROF. GEORGE C. COMSTOCK.

In the *Comptes Rendus* for January 11, 1886, M. LOEWY has suggested the mounting of a prism with silvered faces in front of the objective of an equatorial telescope in such a manner that rays of light coming from two stars in very different parts of the heavens may be simultaneously reflected into the telescope, and he has shown that the angular distance between two stars may be very accurately measured in this way. The distance will be, in fact, twice the angle of the prism plus the apparent distance of the stars as seen in the field of the telescope. In subsequent numbers of the *Comptes Rendus* an analysis is made of the application of this method to the determination of the constant of aberration. A *résumé* of these papers is contained in the *Bulletin Astronomique* for April and June, 1887, and need not be reproduced here, as the purpose of the present article is to consider a single feature of the method, the proper value to be assigned to the angle of the prism.

If we denote by A the angle between the reflecting surfaces of the prism, by d the measured distance between the reflected images of two stars as seen in the field of view of the telescope, and by Δ the angular distance of the two stars, and neglect for the present the effect of refraction upon this distance, we shall have

$$\Delta = 2A + d$$

The effect of aberration upon the apparent distance of two stars is,

$$-2k \cos\beta \sin \tfrac{1}{2}\Delta \;\sin(\odot - \lambda)\,,$$

k denoting the constant of aberration, $\odot$ the sun's longitude, and λ and β the longitude and latitude of the middle point of the arc joining the two stars. If the apparent distance of the stars is measured at the instants when $\odot = \lambda + 90°$ and $\lambda - 90°$, we shall have at these two epochs respectively,

$$\Delta_1 = 2A + d_1 = \Delta_0 - 2k \cos\beta \sin \tfrac{1}{2}\Delta_0$$
$$\Delta_2 = 2A + d_2 = \Delta_0 + 2k \cos\beta \sin \tfrac{1}{2}\Delta_0$$

If it could be assumed that the angle of the prism, A, was

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the same at the two epochs, we should have at once from these equations

$$k = \frac{d_2 - d_1}{4 \cos \beta \sin \frac{1}{2}\Delta_0}$$

but as the two observations are separated by an interval of six months, the assumption of a constant value for A seems hardly permissible. Of the various methods by which the difficulty arising from possible variation of the angle of the prism may be avoided, the most complete one seems to be the use of an equiangular prism, all of whose faces are silvered. Each of the angles of the prism should be used for the measurement of the distances Δ_1 and Δ_2. The quantity A will in this case represent the mean of the three angles of the prism, which must always be 60°. We may even suppose the faces of the prism to be slightly curved, and the normals to these faces not to lie exactly in the same plane, without invalidating the assumption $A =$ a constant; for the prism may be so mounted that the same portion of each face shall always be used, and as this will always be a small surface, and the curvature is supposed small, the face may be assumed to coincide with its osculating sphere. The mean of all the rays reflected from this face will then be parallel to the ray reflected from the tangent plane at the middle point of the face, and for the actual faces of the prism we may suppose the three tangent planes to be substituted. The mean of the three angles of the prism formed by these tangent planes will exceed 60° by one-third the spherical excess of a triangle whose sides are the mutual inclinations of the edges of the prism, a quantity which amounts to only 0″.03 when the inclination of each pair of edges is 5′, which latter quantity is far in excess of any change to be expected in the prism. Should it be thought necessary the inclinations of the edges of the prism can easily be measured, and the mean value of its angles determined with a very high degree of precision; and, in case this were done, observations with the prism would be available for determining the absolute distance of the stars of any pair, thus furnishing a valuable control upon the places of the stars and the systematic errors of star-catalogues.

One apparent objection to the use of a 60° prism, must, however, be considered. The angular distance between the stars to be observed will differ but little from 120°, and, as in a determination of the constant of aberration the middle point of the arc joining the stars must lie near the ecliptic, the stars themselves at the times of observation will be at great zenith distances, where the definition is relatively bad and the images unsteady, conditions which tend to produce large errors of observation. What the actual magnitude of these errors will be can be determined only by the discussion of a series of observations, but the following considerations render it probable that they will not be greater than in the case of stars nearer the zenith.

If we denote the probable error of a determination of k by the symbol $r(k)$ with like expressions for the probable errors of other quantities, we shall have

$$r(k) = \frac{r(d_2 - d_1)}{4 \cos \beta \sin \frac{1}{2}\Delta}$$

The quantities d_2 and d_1 are determined independently, but under similar circumstances, and we may assume

$$r(d_2 - d_1) = \sqrt{2}\, r(d).$$

This quantity $r(d)$ will depend upon the skill of the observer, the character of his instrument, and the atmospheric conditions under which the observations are made. Its absolute magnitude cannot be assigned in advance of observation, but in the absence of other data we may provisionally assume that the variation of $r(d)$ with the zenith distance of the stars observed will in general be similar to that which obtains in the case of probable errors of declinations observed at various zenith distances with a meridian circle. In accordance with this assumption we put

$$r(d) = f \cdot r(\delta),$$

f being some unknown, but constant factor. For the sake of simplicity, I shall assume $f = \sqrt{2}$, a value which is probably much too large, d being the result of a simple differential measurement, while δ is an absolute determination. Making these substitutions, we find

$$r(k) = \frac{r(\delta)}{2 \cos \beta \sin \frac{1}{2}\Delta}$$

To determine the law of variation of $r(\delta)$ with the zenith distance of the body observed, I have discussed the observations made with the meridian circle of the Washburn Observatory from June, 1884, to July, 1885 inclusive. For this purpose I selected four zones, and made use of all stars within these zones which had been observed five or more times by observers H. and C. I thus find the numbers contained in the following table:

Limits of Declination.	No. Stars.	No. Resid.	Mean Z.D.	$r(\delta)$
+37° to +52°	27	226	4°	±0″.34
+ 1 to — 5	34	233	45	0 .41
—22 to —32	42	275	70	0 .51
	11	81	77	0 .64

In the last zone, on account of insufficient data, I have made use of stars on both sides of the zenith, between the limits 75° and 78°.5 zenith distance. These probable errors are represented by the empirical formula

$$r(\delta) = \pm (0''.34 + 0''.07 \tan z)$$

as follows:

0″.34 0″.41 0″.53 0″.64

Whatever objections may be urged against the legitimacy of the assumption upon which the value of $r(\delta)$ at 77° zenith distance was derived, it appears from a comparison of the numbers computed from the formula, with the probable errors derived from the observations themselves, that the

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effect of including this last zone in the derivation of the formula for $r(\delta)$ has not been to increase the accuracy assigned to observations at great zenith distances.

This formula for $r(\delta)$ enables us to express $r(k)$ numerically as follows:

$$r(k) = \pm \frac{0''.34 + 0''.07 \tan z}{2 \cos\beta \sin \frac{1}{2}\Delta}$$

The stars to be observed for a determination of the constant of aberration will be situated near the ecliptic, or near the equator, and as it is desirable that the observations should be made at nearly equal temperatures, the middle point of the arc joining the stars should be about 90° distant from the equinox, which will make corresponding observations occur in the spring and autumn. The zenith distances of the stars at the time of observation will be given for these two cases respectively by the formulas

$$\cos z = \cos(\varphi - \varepsilon) \cos \tfrac{1}{2}\Delta$$
$$\cos z = \cos \varphi \cos \tfrac{1}{2}\Delta$$

ε denoting the obliquity of the ecliptic.

From the preceding formulas, I have computed the values of z and $r(k)$ corresponding to several assumed values of the angle of the prism, and find for the latitudes of the Washburn Observatory, 43°, the following quantities:

Angle of Prism		30°	40°	50°	60°	70°
Arc in Ecliptic	z	35°	44°	52°	62°	71°
	$r(k)$	± 0″.39	0″.32	0″.28	0″.27	0″.29
Arc in Equator	z	51°	56°	62°	69°	76°
	$r(k)$	± 0″.43	0″.34	0″.31	0″.30	0″.33

Beyond 70° the computation ought not to be extended, as the formula for $r(\delta)$ cannot be relied upon beyond the limits of the observations from which it was deduced, but the computation as it stands shows that the probable error of a determination of k passes through a minimum for a value of the angle of the prism, differing but little from 60°. It should, however, be borne in mind that the above values of $r(k)$ cannot be considered as the probable errors of a determination of k; they are simply a series of numbers supposed to be proportional to the probable errors.

From this discussion we conclude that the use of a 60° prism for a determination of the constant of aberration is to be recommended, on the ground that the results are free from systematic error, arising from deformation of the prism between the times of observation, and that the effect of accidental errors of observation is approximately a minimum for this value of the angle. The maximum of simplicity is also secured by this choice of an angle, since a complete determination of the constant can be obtained from each pair of stars observed, while by the methods hitherto proposed two pairs of stars must be combined in order to eliminate the effect of possible variations in the angle of the prism.

Washburn Observatory, Madison, 1887 *December* 2.

OBSERVATIONS OF *X CYGNI*. 7437

20h 37m 43s + 35° 3′.6 (1855).

By S. C. CHANDLER, Jr.

The following are all the maxima and minima of this star which my observations afford to the present time. The epochs are numbered from the maximum occurring nearest the date of discovery. The times of maximum and minimum phases have been determined both by single curve drawings, and by reference to a mean light-curve formed from all the observations. Those here given result from the latter method, although it is doubtful whether, in this case, there is any reason for preference, as the star distinctly belongs to the class whose light-curves are not constant in different periods. Its brightness at minimum, especially, is notably variable, sometimes falling not quite to the star d, at other times a half-magnitude below it. The bright and faint minima do not alternate regularly, so that the star does not belong to the β *Lyræ* type.

E	Observed Maxima.			Observed Minima.		
	Camb. M.T.	O—C	p	Camb. M.T.	O—C	p
	1886 d	d		1886 d	d	
3	Nov. 28.3	—0.9	1	Nov. 25.0	+2.3	½
4	Dec. 13.7	—1.1	1	Dec. 8.6	+0.5	1
5	1887 31.9	+1.5	1	1887 25.0	—1.3	1
6	Jan. 16.1	+1.1	½	Jan. 11.3	+0.8	1
22	Sept. 21.2	—0.4	½			
23	Oct. 7.4	+0.2	1			
24	22.7	—0.1	1	Oct. 15.3	—0.3	1
25	Nov. 8.3	+0.9	1	31.1	—1.7	1
26	23.7	+0.7	1	Nov. 16.9	—0.5	1
27				Dec. 4.3	+1.3	1

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RING-MICROMETER OBSERVATIONS OF COMET *e* 1887,

MADE WITH A CLACEY 6¼-INCH REFRACTOR,

BY S. C. CHANDLER, JR.

1887 Cambridge M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
May 30 10 33 53	1	4	+1 10.70	+ 3 19.4	15 43 20.62	—18 48 41.3	n8.845	0.887
30 10 59 43	2	4	+2 51.27	— 0 53.7	15 43 22.16	—18 47 43.5	n8.322	0.888
30 11 10 46	3	2	—1 46.06	—11 43.6	15 43 23.46	—18 47 27.3		0.882
July 12 9 27 58	4	10	+1 5.78	— 0 26.8	17 17 56.33	+ 6 45 58.1	n8.716	0.710
12 10 6 14	5	10	—2 3.37	+ 0 21.8	17 18 0.89	+ 6 46 22.0	8.341	0.718

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 42 7.82	+2.10	—18 52 0.6	— 0.1	Oe. Argel. 14900
2	15 40 28.79	+2.10	—18 46 49.7	— 0.1	Oe. Argel. 14867, 8
3	15 45 7.42	+2.10	—18 35 43.6	— 0.1	Oe. Argel. 14931
4	17 16 48.44	+2.11	+ 6 46 14.8	+10.1	BB. VI. +6° 3403
5	17 20 2.15	+2.11	+ 6 45 50.1	+10.1	BB. VI. +6° 3413

FILAR-MICROMETER OBSERVATIONS OF COMET 1887 *f* (*Olbers*),

MADE AT THE DUDLEY OBSERVATORY,

BY H. V. EGBERT.

1887 Albany M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Sept. 15 16 7 23	1	14	+0 29.70	—0 39.3	10 11 44.12	+30 0 30.6	n9.698	0.741
Nov. 1 17 33 7	2	5	—1 58.37	—0 40.1	13 49 21.54	+17 33 56.3	n9.655	0.735

Mean Places for 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	10 11 14.37	+0.05	+30 1 17.3	—7.4	Leiden Zones 37, 68–39, 68
2	13 51 19.75	+0.16	+17 34 38.7	—2.3	W.B. 1088 (Lal. 25649)

CORRIGENDA.

No. 162 p. 141. Col. 1, line 8, the numerator should be $y'z—yz'$.

line 35. Second equation should be $\frac{N—\nu N''}{a_0} = l$.

p. 143. First column of table, last line, for 0.000 put 0.009.
Recapitulation, line 10, for e put e'.
line 12, for ψ put ψ''.
line 18, for $L—L$ put $L''—L$.

p. 144. Col. 1, line 3, for $+\chi$ put $\chi+$.
line 6, for p put $\sqrt{p}$,

CONTENTS.

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ON A METHOD OF COMPUTING AN ORBIT FROM THREE OBSERVATIONS,

BY REV. GEORGE M. SEARLE.

(Continued from No. 162.)

In any method of computing an orbit, the approximation may easily be carried far beyond the accuracy of the observations on which the computation is based, and thus much time wasted.

To see how far it is worth while to continue the approximation, it may be well to have some method of comparing the middle place which would be computed from the elements resulting from any hypothesis, with observation, without actually computing those elements and the middle place from them.

To do this, we may first compute the values of f, f'', and r', which would result for the time t' from the elements.

In order to this, we will first take the trigonometrical formula, true for any values of A and B,

$$\sin^2(A+B) = \sin^2 A + \sin^2 B + 2\sin A \sin B \cos(A+B)$$

In this, making $g=A$, $g''=B$, $g'=A+B$, we have putting for $\sin g$ the value $\dfrac{\sqrt{r'r''}\sin f}{b}$ and similarly for g' and g'', and multiplying by $\dfrac{b^2}{rr'r''}$, the equation

$$\frac{\sin^2 f'}{r'} = \frac{\sin^2 f}{r} + \frac{\sin^2 f''}{r''} + 2\frac{\sin f}{\sqrt{r}}\cdot\frac{\sin f''}{\sqrt{r''}}\cos g'$$

or making $\sigma = \dfrac{\sin f}{\sqrt{r}}$ and similarly σ' and σ''

$$\sigma'^2 = \sigma^2 + \sigma''^2 + 2\sigma\sigma''\cos g'$$

It may be here remarked, that by obtaining the value of $\cos g'$ from this equation, and putting

$$b^{-2} = \frac{(1+\cos g')(1-\cos g')}{rr''\sin^2 f'}$$

we can deduce the expression used in this method to obtain b^{-2}.

Having then obtained σ' from the values of σ, σ'', and g' $\left[=\dfrac{\epsilon-\delta}{2}\right]$ furnished by the hypothesis, $\dfrac{\sin^2 f'}{\sigma'^2}$ will denote the radius vector of the orbit where it cuts the r' which has been computed; or in other words the radius vector corresponding to f and f'' in the orbit. We will denote this by r'_0.

Now obviously

$$\sin g = \frac{\sigma}{\sigma'}\sin g'; \quad \text{and } \sin g'' = \frac{\sigma''}{\sigma'}\sin g',$$

g and g'' answering to f and f'' in the orbit; and by these and the value of p which we have from the hypothesis [which can also be computed by the formula $p = \dfrac{rr''\sin^2 f'}{a\sin^2 g'}$ if g' has been obtained by the trial with sufficient accuracy] and the value of r'_0 just deduced, we shall have the values of η and η'' strictly corresponding with f and f'' in the orbit resulting from the hypothesis; and hence t'_0, the time at which a heavenly body moving in this orbit would cross r', by the formula

$$t'_0 = t + \frac{t''-t}{1+\dfrac{\eta}{\eta''}}.$$

Let us denote $t'-t'_0$ by dt. We have then for ds, the distance traversed by the body in the time dt, the expression,

$$k\sqrt{\frac{2}{r'}-\frac{1}{a}}\,dt$$

Let us also denote $r'_0 - r'$ by dr'.

Now the angular divergence of the computed place from the observed, which latter corresponds to the end of r', will evidently be the resultant of dr' and ds, projected on a plane perpendicular to Δ' the line joining the earth and the heavenly body, and divided by Δ'. The square of this projection is equal to the square of the whole resultant minus the square of its projection on Δ'.

Now the projection of dr' on $\Delta' = dr'\cos z$, if by z we denote the angle formed at the body between r' and Δ'. The projection of ds on Δ' is the increase of Δ' in dt, minus the increase of Δ' produced by the motion of the earth in dt. This latter is approximately equal to $k\cos\beta'\sin(\lambda'-L')\,dt$, since the earth is moving toward $L'-90$ with a velocity of k,

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and the cosine of the angle its line of motion forms with the line leading away from the body is $\cos\beta'\cos[\lambda'-180°-(L'-90°)]$. Hence the whole projection on Δ' of dr' and ds, which we will denote by $d\Delta'$, is equal approximately to

$$\left[\frac{\Delta''-\Delta}{t''-t}-k\cos\beta'\sin(\lambda'-L')\right]dt+dr'\cdot\cos z$$

The square of the whole resultant is equal to $(dr')^2+(ds)^2-2dr'\cdot ds\cdot\cos\gamma$ in which γ is the angle formed by r' with ds. We have then finally

$$[d\lambda'\cos\beta']^2+[d\beta']^2=\frac{[dr']^2+[ds]^2-2dr'\cdot ds\cdot\cos\gamma-[d\Delta']^2}{\Delta'^2}$$

in which γ is obtained by the formula

$$\sin\gamma=\frac{r'dv'}{ds}=\frac{k\sqrt{p}}{r'}\,\frac{dt}{ds},$$

and $\gamma>90$ when r' is increasing.

For z we have $\cos\psi'=\cos\beta'\cos(\lambda'-L')$, $\sin z=\dfrac{R'\sin\psi'}{r'}$. $z>90$ when $R'\cos\psi'>\Delta'$.

Condensation of the above Formulas.

Compute $\sigma=\dfrac{\sin f}{\sqrt{r}}$ $\quad\sigma''=\dfrac{\sin f''}{\sqrt{r}}$

$\sigma'^2=\sigma^2+\sigma''^2+2\sigma\sigma''\cos g'$ or $=(\sigma+\sigma'')^2-4\sigma\sigma''\sin^2\frac{1}{2}g'$

in which $g'=\dfrac{\epsilon-\delta}{2}$ of the hypothesis, or zero for the parabola.

$$\text{Then}\quad r'_0=\frac{\sin^2 f'}{\sigma'^2};\quad \sin g=\frac{\sigma}{\sigma'}\sin g';\quad \sin g''=\frac{\sigma''}{\sigma'}\sin g'$$

$$\eta=1+\frac{2\sqrt{r'_0}}{3p}w\sqrt{r''}\sin f\tan f$$

$$\eta''=1+\frac{2\sqrt{r'_0}}{3p}w''\sqrt{r}\sin f''\tan f''$$

$$\frac{\eta}{\eta''}\nu=\tau;\quad dt=\frac{\tau(t'-t)-(t''-t')}{1+\tau}$$

$$ds=k\sqrt{\frac{2}{r'}-\frac{1}{a}}\,dt;\quad dr'=r'_0-r'$$

$$\cos\psi'=\cos\beta'\cos(\lambda'-L');\ \sin z=\frac{R'\sin\psi'}{r'};$$

$$z>90\text{ when }R'\cos\psi'>\Delta'$$

$$\sin\gamma=\frac{k\sqrt{p}}{r'}\cdot\frac{dt}{ds};\qquad \gamma>90\text{ when }r'\text{ is increasing}$$

$$d\Delta'=\left[\frac{\Delta''-\Delta}{t''-t}-k\cos\beta'\sin(\lambda'-L')\right]dt+\cos z\cdot dr'$$

$$[d\lambda'\cos\beta']^2+[d\beta']^2=\frac{(dr')^2+(ds)^2-2dr'\cdot ds\cdot\cos\gamma-(d\Delta')^2}{\Delta'^2}$$

In these formulas, z, γ, $\dfrac{ds}{dt}$, $\dfrac{d\Delta'}{dt}$, will not vary, at least materially, from one hypothesis to another. Δ' may be obtained with sufficient accuracy by interpolating between Δ and Δ'', or by $\Delta'=\dfrac{r'\sin(\psi'+z)}{\sin\psi'}$.

The greater part of this computation may, owing to the smallness of the quantities, be made with *four*, *or even three*, places of logarithms.

It will perhaps be well to compute b^{-2} for the next hypothesis by putting

$$\sigma'=\frac{\sin f'}{\sqrt{r'}}\qquad s=\frac{\sin f}{\sigma'\sqrt{r}}\qquad s''=\frac{\sin f''}{\sigma'\sqrt{r''}}$$

$$4\sin^2\tfrac{1}{2}g'=\frac{(s+s''+1)(s+s''-1)}{ss''};\quad b^{-2}=\frac{4\sin^2\frac{1}{2}g'}{rr''\sin^2 f'}\cos^2\tfrac{1}{2}g'$$

We shall then have

$$dr'=4ss''\cdot r'_0\sin\tfrac{1}{2}(g'_0+g')\sin\tfrac{1}{2}(g'_0-g')$$

in which $g'_0=\dfrac{\epsilon-\delta}{2}$ of the hypothesis. For r'_0 we may write r' with sufficient accuracy. We then have $r'_0=r'+dr'$

$$\sin g=s\sqrt{\frac{r'_0}{r'}}\sin g'_0\qquad \sin g''=s''\sqrt{\frac{r'_0}{r'}}\sin g'_0$$

$$g+g''\text{ should be equal to }g'_0$$

Then taking out w and w'' for g and g'', and computing p either by η' and

$$\sqrt{p}=\frac{\eta' rr''\sin 2f'}{k(t''-t)}\quad\text{or}\quad\text{by }p=\frac{rr''\sin^2 f'}{a\sin^2 g'_0}$$

in which, of course, a is the value used for the hypothesis, we have η and η'' by the formulas above and $\nu=\dfrac{\eta''}{\eta}\,\dfrac{(t''-t')}{(t'-t)}$ for the next hypothesis.

For computing the middle place, as we may wish to do it more than once, it may be as well to obtain z and γ, roughly once for all, also

$$\frac{ds}{dt}=k\sqrt{\frac{2}{r'}-\frac{1}{a}};\qquad \frac{d\Delta'}{dt}=\frac{\Delta''-\Delta}{t''-t}-k\cos\beta'\sin(\lambda'-L'),$$

to which last, if we wish to take account of second differences, we may add the term $+\dfrac{2e^2}{(t'-t)(t''-t')}\left[\dfrac{\Delta''-\Delta}{t''-t}-\dfrac{f}{e}\right]$ in which $e=t'-\frac{1}{2}(t+t'')$ and $f=\Delta'-\frac{1}{2}(\Delta+\Delta'')$.

We then shall have, making

$$m=\left(\frac{ds}{dt}\right)^2-\left(\frac{d\Delta'}{dt}\right)^2,\quad\text{and } n=2\left[\frac{ds}{dt}\cos\gamma+\frac{d\Delta'}{dt}\cos z\right],$$

$$(d\lambda'\cos\beta')^2+(d\beta')^2=\frac{\sin^2 z\cdot(dr')^2+m(dt)^2-ndr'\cdot dt}{\Delta'^2}$$

in which dr' is to be computed for each hypothesis by the formula above, and dt by $dt=\dfrac{\tau(t'-t)-(t''-t)}{1+\tau}$; the rest of the second member being nearly constant.

It is evident that if we are already possessed of even a rough ephemeris giving Δ', the values of Δ' and $\dfrac{d\Delta'}{dt}$ may be more easily obtained, taking care of course to correct the latter for the motion of the earth by the term $k\cos\beta'\sin(\lambda'-L')$, in which if greater accuracy is desired, we may multiply k by $\sqrt{\dfrac{2}{R'}-1}$ and increase $\lambda'-L'$ by $\tan^{-1}\dfrac{dR'}{R'dL'}=\tan^{-1}2.303\,\dfrac{d\log R'}{dL'}$. This angle is always less than one degree, but can be easily obtained from the almanac.

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The following elements were computed by this process for the Olbers comet from normal places for August 28 and September 21, together with an observation on October 19, kindly furnished by Mr. WENDELL of Harvard College Observatory, by permission of Prof. PICKERING:

$$\begin{aligned} T &= \text{Oct. } 8.4584 \text{ G.M.T.} \\ \left.\begin{aligned} \Omega &= 84^\circ\ 29'\ 18''.4 \\ i &= 44\ \ 33\ \ 57\ .4 \\ \omega &= 65\ \ 19\ \ 25\ .6 \end{aligned}\right\} & \ 1887.0 \\ \log e &= 9.968896 \\ \log a &= 1.239284 \\ \text{Period} &= 72.26 \text{ years.} \end{aligned}$$

The last hypothesis but one, corresponding to a period of 74.7 years, gave a discordance for the middle place, according to the formulas just given, of only $2''.2$; it might therefore well be doubted whether it would be worth while to make another, had the orbit been quite unknown, especially as the third place depended on a single observation.

The coefficients of $(dr')^2$, $(dt)^2$, and $dr' \cdot dt$, are of course conveniently multiplied by $(206265)^2$ in order that the discordance may be expressed in seconds of arc.

OBSERVATIONS OF VARIABLE STARS IN 1886 — (*Continued*),

BY EDWIN F. SAWYER.

1. *R Coronae.*

This star was under observation from March 4 to November 14, 27 observations being obtained. The observed fluctuations of light were very small, not over 2 or 3 steps. *R* was brightest during August, when it was 5+ steps > DM. 30°,2682, and only 2 steps < DM. 32°,2621, or about $6^{\text{M}}.2$.

2. *S Coronae.*

Only 11 observations were obtained on this star, extending from March 28 to July 19. When first seen on March 28, *S* was 5+ steps < DM. 32°,2577, or about $8^{\text{M}}.6$. The increase of light was rather rapid, and a maximum was passed on May 10. The maximum brightness 5+ steps > DM. 32°,2575, and = DM. 32°,2578, or $7^{\text{M}}.6$, this representing rather a faint maximum. The light remained apparently constant from April 21 to June 4, or 44 days. The decrease of light was slow, and when last observed, on July 19, *S* was 5 steps < DM. 32°,2575, or about $8^{\text{M}}.6$.

3. *V Cancri.*

This star was observed on 11 evenings, from February 28 to April 29. When first seen on February 28, *V* was 5+ steps < DM. 18°,1923 and = DM. 18°,1917, or $8^{\text{M}}.7$. The increase of light was quite rapid, a maximum being passed on March 29. Maximum brightness = DM. 18°,1931, or about $7^{\text{M}}.7$. When last observed, on April 29, it was 2 steps > DM. 18°,1923, and 5 steps < DM. 18°,1931, or $8^{\text{M}}.1$.

4. *R Scuti.*

A good series of observations, 38 in number, was obtained on this star, extending from June 4 to December 14. These observations when charted exhibited only one maximum and two minima. The first minimum was passed on July 21, and was a bright one; light = 7.4 of my scale. The second minimum was a faint one, and was reached on December 2; light = 0.0. The interval between the two minima = 134 days. The only maximum observed was passed on September 12, and was rather a faint one; light = 17.2. The light at maximum remained nearly constant from August 5 to October 20, a period of 76 days.

5. *o Ceti.*

A good series of observations, 41 in number, was obtained on this star, extending from 1885 October 10 to 1886 March 7. The increase of light was rapid, and a maximum was reached on January 9. Maximum brightness, 5 steps > 237 (*U.A.*) *Ceti*, and 3 steps < 270 (*U.A.*) *Ceti*, or $5^{\text{M}}.4$; this representing a faint maximum. The light remained apparently constant for the 35 days from 1885 December 28 to 1886 February 1. The decrease of light was quite rapid after February 1.

6. *36* (*U.A.*) *Ceti.*

19 observations were obtained on this star, extending from September 29 to 1887 January 27. When first seen it was 1 step > 28 (*U.A.*) *Ceti*, and 4 steps < 10 (*U.A.*) *Ceti*, or $6^{\text{M}}.6$. The increase of light from September 29 to October 23 was rapid. The light remained apparently constant from October 24 to November 14, when a further increase occurred. A maximum was reached on December 6; maximum brightness 5 steps > 7 (*U.A.*) *Ceti*, and 1 step < 18 (*U.A.*) *Ceti*, or $5^{\text{M}}.4$. The light remained at a standstill from November 19 to December 25, or 36 days. The decrease of light was also rapid, and when last observed, the star was 2 steps > 28 (*U.A.*) *Ceti*, and 5 steps < 7 (*U.A.*) *Ceti*, or $6^{\text{M}}.4$.

7. *W Cygni* (GORE 1885).

$21^{\text{h}}\ 30^{\text{m}}\ 33^{\text{s}}.9,\ +44^\circ\ 43'.7\ (1855.0).$

This star was under observation from 1886 May 1 to 1887 February 20, 43 observations being obtained. These observations when charted exhibit one well determined maxi-

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mum and two minima. The first minimum occurred on July 8, the minimum brightness being 1 step > DM. 43°,4002, and 4 steps < DM. 44°,3889, or 6ᵐ.7. The second minimum, of the same brightness, was passed on November 5, the interval between the two minima being 120 days. The maximum occurred on September 10, when the brightness was 2 steps > DM. 44°,3889, and 4 steps < DM. 46°,3305, or 6ᵐ.3. A maximum also occurred about May 14 (increase of light not well observed), and the star was again apparently at maximum when the observations terminated.

8. *ρ Persei.*

The observations on this star were continued (from the series published in No. 151 of this Journal, and extending from January 1) until April 22, and also from October 2 to December 24, 18 observations. The light remained nearly constant until November 4, when it decreased 4 or 5 steps, and so remained until December 21. The minimum occurred about November 24.

9. *R Virginis.*

This star was observed on 12 evenings, from March 6 to April 29. When first seen, *R* was 5+ steps < DM. 8°,2626, or about 9ᵐ.0. The increase of light was rapid and uniform, a maximum being passed on April 8. Maximum brightness 3 steps > DM. 8°,2634, and 4 steps < combined light of DM. 8°,2620, 21, or about 8ᵐ.0: this representing a faint maximum. When last observed, *R* was = DM. 8°,2634, and 3 steps > DM. 8°,2626, or 8ᵐ.2.

10. *g Herculis.*

The observations on this star extended from March 28 to November 27, and are 25 in number. The charted observations exhibit but one maximum and one minimum. The minimum occurred on June 14, and was a faint one. The maximum was passed about September 20. The light remained nearly constant from July 19 to November 4, a period of 108 days.

11. *R Ursæ Majoris.*

8 scattering observations were obtained on this star, extending from March 24 to June 4. When first seen, *R* was 5+ steps < DM. 70,622, or about 8ᵐ.8. The increase of light appeared quite rapid, and a maximum was passed about April 29. When last observed, on June 4, *R* was = DM. 69°.584, and 3 steps < DM. 69°.579, or 8ᵐ.2.

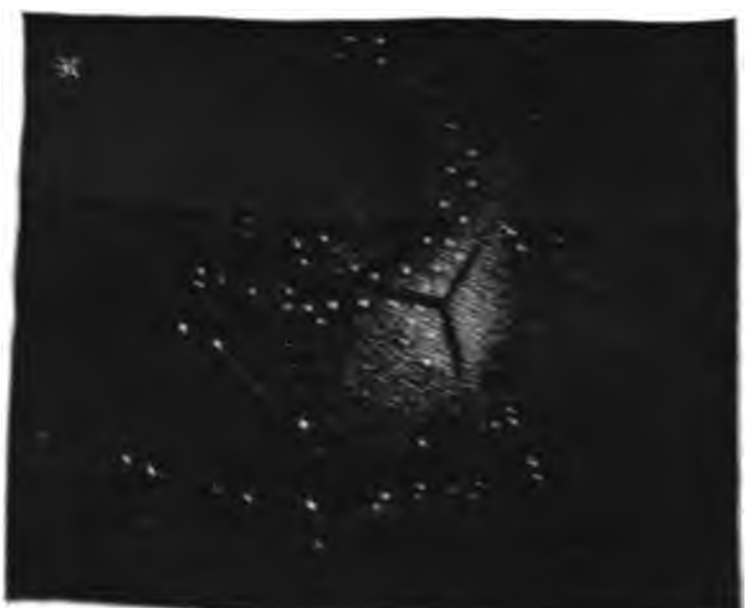
Cambridgeport, 1887 September 13.

ON THE STRUCTURE OF *13 M HERCULIS.*

By Prof. MARK W. HARRINGTON.

The great cluster in *Hercules* has been frequently figured and always, with one exception, as a globular mass of stars much condensed in the center. Lord Rosse's observers alone found it crossed by three dark rifts, as shown in Figure 1, which is a copy of their drawing, the position only being changed in order to bring the notable hook above.

FIG. 1. THE GREAT CLUSTER AS SEEN IN LORD ROSSE'S REFLECTING TELESCOPE — THE HOOK ABOVE.



Last spring I spent some time in studying this cluster with the aid of Mr. H. C. MARKHAM, an artist whose sight I have found to be remarkably keen. We very soon found that under favorable circumstances, and with high powers, we were able to see the rifts which had been figured by Lord ROSSE, and this was done before Mr. MARKHAM knew of Lord ROSSE's drawing. The rifts were somewhat difficult objects, but with proper precautions, they were frequently seen by Mr. MARKHAM and myself, and also by Assistant SCHAEBERLE. After following them for about a month the drawing, Figure 2, was made. I could not, however, make any measurements, as after illumination of the wires of my micrometer, I could not see the rifts.

The rifts were seen with both th[illegible] equatorials. They came out more [illegible] increase of magnifying power, until 50[illegible] With higher powers the rifts seemed to [illegible] and the cluster broke up into small cl[illegible] stars.

The resemblance of Figure 2 to Figur[illegible] Taking the hook above as a starting p[illegible] canals radiating in the one case as in the [illegible]

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The absence of the brighter outlying stars in Figure 2 is without significance, as no attempt was made to include them. Aside from that, while the general resemblance between the two figures is notable, the differences in detail are remarkable. The upper or south rift is much broader and shorter in the later figure. The preceding rift is the best marked, and is much alike in the two drawings. The north or lower rift is much less marked, and is decidedly shorter in the later figure. In Lord Rosse's drawing the radiating point of the rifts is nearly central; in Mr. Markham's it is shifted backwards. In the first the central condensation is not marked; in the second it is preceding and slightly below the radiating point. I may say that the drawing was made before we permitted ourselves to refer to Lord Rosse's drawing. As to the significance of these rifts I can not make any suggestion. They are so elusive that I sometimes almost doubted their existence, but I found that with patience I could always see them; and when after the completion of our drawing we finally compared it with Lord Rosse's, we could no longer doubt that we had seen what had been seen by his observers. Whatever the rifts are, it seems certain that they have shifted their position slightly in the fifty or more years which have elapsed since the first drawing was made.

Fig. 2. The Great Cluster with a Power of 500 or 600, Ann Arbor.

H. Markham. April 13, 1887. 11 P.M.

Observatory, Ann Arbor, 1887 *August* 29.

NOTE ON THE DETERMINATION OF THE CONSTANT OF ABERRATION,

By Prof. GEORGE C. COMSTOCK.

In the *Comptes Rendus* for January 11, 1886, M. Loewy has suggested the mounting of a prism with silvered faces in front of the objective of an equatorial telescope in such a manner that rays of [illegible] coming from two stars in very different parts of the [illegible] may be simultaneously reflected into the [illegible] that the angular distance [illegible] very accurately measured in [illegible], in fact, twice the angle of [illegible] distance of the stars as [illegible] In subsequent numbers of [illegible] is made of the application [illegible] ation of the con[illegible] pers is contained [illegible] June, 1887, and [illegible] of the present [illegible] the method, the [illegible] the prism. [illegible] reflecting sur[illegible] nce between the reflected images of two stars as seen in the field of view of the telescope, and by Δ the angular distance of the two stars, and neglect for the present the effect of refraction upon this distance, we shall have

$$\Delta = 2A + d$$

The effect of aberration upon the apparent distance of two stars is,

$$-2k \cos\beta \sin\tfrac{1}{2}\Delta \quad \sin(\odot - \lambda),$$

k denoting the constant of aberration, $\odot$ the sun's longitude, and λ and β the longitude and latitude of the middle point of the arc joining the two stars. If the apparent distance of the stars is measured at the instants when $\odot = \lambda + 90°$ and $\lambda - 90°$, we shall have at these two epochs respectively,

$$\Delta_1 = 2A + d_1 = \Delta_0 - 2k \cos\beta \sin\tfrac{1}{2}\Delta_0$$
$$\Delta_2 = 2A + d_2 = \Delta_0 + 2k \cos\beta \sin\tfrac{1}{2}\Delta_0$$

If it could be assumed that the angle of the prism, A, was

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mum and two minima. The first minimum occurred on July 8, the minimum brightness being 1 step > DM. 43°,4002, and 4 steps < DM. 44°,3889, or $6^{M}.7$. The second minimum, of the same brightness, was passed on November 5, the interval between the two minima being 120 days. The maximum occurred on September 10, when the brightness was 2 steps > DM. 44°,3889, and 4 steps < DM. 46°,3305, or $6^{M}.3$. A maximum also occurred about May 14 (increase of light not well observed), and the star was again apparently at maximum when the observations terminated.

8. *ρ Persei.* 1572

The observations on this star were continued (from the series published in No. 151 of this Journal, and extending from January 1) until April 22, and also from October 2 to December 24, 18 observations. The light remained nearly constant until November 4, when it decreased 4 or 5 steps, and so remained until December 21. The minimum occurred about November 24.

9. *R Virginis.* 4521

This star was observed on 12 evenings, from March 6 to April 29. When first seen, *R* was 5+ steps < DM. 8°,2626, or about $9^{M}.0$. The increase of light was rapid and uniform, a maximum being passed on April 8. Maximum brightness 3 steps > DM. 8°,2634, and 4 steps < combined light of DM. 8°,2620, 21, or about $8^{M}.0$; this representing a faint maximum. When last observed, *R* was = DM. 8°,2634, and 3 steps > DM. 8°,2626, or $8^{M}.2$.

10. *g Herculis.* 5912

The obervations on this star extended from March 28 to November 27, and are 25 in number. The charted observations exhibit but one maximum and one minimum. The minimum occurred on June 14, and was a faint one. The maximum was passed about September 20. The light remained nearly constant from July 19 to November 4, a period of 108 days.

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Cambridgeport, 1887 *September* 13.

ON THE STRUCTURE OF *13 M HERCULIS*,

By Prof. MARK W. HARRINGTON.

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Fig. 1. The Great Cluster as seen in Lord Rosse's Reflecting Telescope — the Hook above.

Last spring I spent some time in studying this cluster with the aid of Mr. H. C. Markham, an artist whose sight I have found to be remarkably keen. We very soon found that under favorable circumstances, and with high powers, we were able to see the rifts which had been figured by Lord Rosse, and this was done before Mr. Markham knew of Lord Rosse's drawing. The rifts were somewhat difficult objects, but with proper precautions, they were frequently seen by Mr. Markham and myself, and also by Assistant Schaeberle. After following them for about a month the drawing, Figure 2, was made. I could not, however, make any measurements, as after illumination of the wires of my micrometer, I could not see the rifts.

The rifts were seen with both the 6-inch and 12-inch equatorials. They came out more and more plainly with increase of magnifying power, until 500 or 600 was reached. With higher powers the rifts seemed to increase and spread, and the cluster broke up into small clusters and scattered stars.

The resemblance of Figure 2 to Figure 1 is unmistakable. Taking the hook above as a starting point we have the three canals radiating in the one case as in the other.

The absence of the brighter outlying stars in Figure 2 is without significance, as no attempt was made to include

Fig. 2. The Great Cluster with a Power of 500 or 600, Ann Arbor.

H. Markham. April 13, 1887. 11 P.M.

them. Aside from that, while the general resemblance between the two figures is notable, the differences in detail are remarkable. The upper or south rift is much broader and shorter in the later figure. The preceding rift is the best marked, and is much alike in the two drawings. The north or lower rift is much less marked, and is decidedly shorter in the later figure. In Lord Rosse's drawing the radiating point of the rifts is nearly central; in Mr. Markham's it is shifted backwards. In the first the central condensation is not marked; in the second it is preceding and slightly below the radiating point. I may say that the drawing was made before we permitted ourselves to refer to Lord Rosse's drawing. As to the significance of these rifts I can not make any suggestion. They are so elusive that I sometimes almost doubted their existence, but I found that with patience I could always see them; and when after the completion of our drawing we finally compared it with Lord Rosse's, we could no longer doubt that we had seen what had been seen by his observers. Whatever the rifts are, it seems certain that they have shifted their position slightly in the fifty or more years which have elapsed since the first drawing was made.

Observatory, Ann Arbor, 1887 *August* 29.

NOTE ON THE DETERMINATION OF THE CONSTANT OF ABERRATION,

By Prof. GEORGE C. COMSTOCK.

In the *Comptes Rendus* for January 11, 1886, M. Loewy has suggested the mounting of a prism with silvered faces in front of the objective of an equatorial telescope in such a manner that rays of light coming from two stars in very different parts of the heavens may be simultaneously reflected into the telescope, and he has shown that the angular distance between two stars may be very accurately measured in this way. The distance will be, in fact, twice the angle of the prism plus the apparent distance of the stars as seen in the field of the telescope. In subsequent numbers of the *Comptes Rendus* an analysis is made of the application of this method to the determination of the constant of aberration. A *résumé* of these papers is contained in the *Bulletin Astronomique* for April and June, 1887, and need not be reproduced here, as the purpose of the present article is to consider a single feature of the method, the proper value to be assigned to the angle of the prism.

If we denote by A the angle between the reflecting surfaces of the prism, by d the measured distance between the reflected images of two stars as seen in the field of view of the telescope, and by Δ the angular distance of the two stars, and neglect for the present the effect of refraction upon this distance, we shall have

$$\Delta = 2A + d$$

The effect of aberration upon the apparent distance of two stars is,

$$-2k \cos\beta \sin\tfrac{1}{2}\Delta \sin(\odot - \lambda),$$

k denoting the constant of aberration, $\odot$ the sun's longitude, and λ and β the longitude and latitude of the middle point of the arc joining the two stars. If the apparent distance of the stars is measured at the instants when $\odot = \lambda + 90°$ and $\lambda - 90°$, we shall have at these two epochs respectively,

$$\Delta_1 = 2A + d_1 = \Delta_0 - 2k \cos\beta \sin\tfrac{1}{2}\Delta_0$$
$$\Delta_2 = 2A + d_2 = \Delta_0 + 2k \cos\beta \sin\tfrac{1}{2}\Delta_0$$

If it could be assumed that the angle of the prism, A, was

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the same at the two epochs, we should have at once from these equations

$$k = \frac{d_2 - d_1}{4 \cos\beta \sin\frac{1}{2}\Delta_0}$$

but as the two observations are separated by an interval of six months, the assumption of a constant value for A seems hardly permissible. Of the various methods by which the difficulty arising from possible variation of the angle of the prism may be avoided, the most complete one seems to be the use of an equiangular prism, all of whose faces are silvered. Each of the angles of the prism should be used for the measurement of the distances Δ_1 and Δ_2. The quantity A will in this case represent the mean of the three angles of the prism, which must always be 60°. We may even suppose the faces of the prism to be slightly curved, and the normals to these faces not to lie exactly in the same plane, without invalidating the assumption $A =$ a constant; for the prism may be so mounted that the same portion of each face shall always be used, and as this will always be a small surface, and the curvature is supposed small, the face may be assumed to coincide with its osculating sphere. The mean of all the rays reflected from this face will then be parallel to the ray reflected from the tangent plane at the middle point of the face, and for the actual faces of the prism we may suppose the three tangent planes to be substituted. The mean of the three angles of the prism formed by these tangent planes will exceed 60° by one-third the spherical excess of a triangle whose sides are the mutual inclinations of the edges of the prism, a quantity which amounts to only 0″.03 when the inclination of each pair of edges is 5′, which latter quantity is far in excess of any change to be expected in the prism. Should it be thought necessary the inclinations of the edges of the prism can easily be measured, and the mean value of its angles determined with a very high degree of precision; and, in case this were done, observations with the prism would be available for determining the absolute distance of the stars of any pair, thus furnishing a valuable control upon the places of the stars and the systematic errors of star-catalogues.

One apparent objection to the use of a 60° prism, must, however, be considered. The angular distance between the stars to be observed will differ but little from 120°, and, as in a determination of the constant of aberration the middle point of the arc joining the stars must lie near the ecliptic, the stars themselves at the times of observation will be at great zenith distances, where the definition is relatively bad and the images unsteady, conditions which tend to produce large errors of observation. What the actual magnitude of these errors will be can be determined only by the discussion of a series of observations, but the following considerations render it probable that they will not be greater than in the case of stars nearer the zenith.

If we denote the probable error of a determination of k by the symbol $r(k)$ with like expressions for the probable errors of other quantities, we shall have

$$r(k) = \frac{r(d_2 - d_1)}{4 \cos\beta \sin\frac{1}{2}\Delta}$$

The quantities d_2 and d_1 are determined independently, but under similar circumstances, and we may assume

$$r(d_2 - d_1) = \sqrt{2}\, r(d).$$

This quantity $r(d)$ will depend upon the skill of the observer, the character of his instrument, and the atmospheric conditions under which the observations are made. Its absolute magnitude cannot be assigned in advance of observation, but in the absence of other data we may provisionally assume that the variation of $r(d)$ with the zenith distance of the stars observed will in general be similar to that which obtains in the case of probable errors of declinations observed at various zenith distances with a meridian circle. In accordance with this assumption we put

$$r(d) = f \cdot r(\delta),$$

f being some unknown, but constant factor. For the sake of simplicity, I shall assume $f = \sqrt{2}$, a value which is probably much too large, d being the result of a simple differential measurement, while δ is an absolute determination. Making these substitutions, we find

$$r(k) = \frac{r(\delta)}{2 \cos\beta \sin\frac{1}{2}\Delta}$$

To determine the law of variation of $r(\delta)$ with the zenith distance of the body observed, I have discussed the observations made with the meridian circle of the Washburn Observatory from June, 1884, to July, 1885 inclusive. For this purpose I selected four zones, and made use of all stars within these zones which had been observed five or more times by observers H. and C. I thus find the numbers contained in the following table:

Limits of Declination.	No. Stars.	No. Resid.	Mean Z.D.	$r(\delta)$
+37° to +52°	27	226	4°	±0″.34
+ 1 to — 5	34	233	45	0 .41
—22 to —32	42	275	70	0 .51
	11	81	77	0 .64

In the last zone, on account of insufficient data, I have made use of stars on both sides of the zenith, between the limits 75° and 78°.5 zenith distance. These probable errors are represented by the empirical formula

$$r(\delta) = \pm(0''.34 + 0''.07 \tan z)$$

as follows:

0″.34 0″.41 0″.53 0″.64

Whatever objections may be urged against the legitimacy of the assumption upon which the value of $r(\delta)$ at 77° zenith distance was derived, it appears from a comparison of the numbers computed from the formula, with the probable errors derived from the observations themselves, that the

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effect of including this last zone in the derivation of the formula for $r(\delta)$ has not been to increase the accuracy assigned to observations at great zenith distances.

This formula for $r(\delta)$ enables us to express $r(k)$ numerically as follows:

$$r(k) = \pm \frac{0''.34 + 0''.07 \tan z}{2 \cos \beta \sin \frac{1}{2} \Delta}$$

The stars to be observed for a determination of the constant of aberration will be situated near the ecliptic, or near the equator, and as it is desirable that the observations should be made at nearly equal temperatures, the middle point of the arc joining the stars should be about 90° distant from the equinox, which will make corresponding observations occur in the spring and autumn. The zenith distances of the stars at the time of observation will be given for these two cases respectively by the formulas

$$\cos z = \cos(\varphi - \varepsilon) \cos \tfrac{1}{2} \Delta$$
$$\cos z = \cos \varphi \cos \tfrac{1}{2} \Delta$$

ε denoting the obliquity of the ecliptic.

From the preceding formulas, I have computed the values of z and $r(k)$ corresponding to several assumed values of the angle of the prism, and find for the latitudes of the Washburn Observatory, 43°, the following quantities:

Angle of Prism		30°	40°	50°	60°	70°
Arc in Ecliptic	z	35°	44°	52°	62°	71°
	$r(k)$ ±	0″.39	0″.32	0″.28	0″.27	0″.29
Arc in Equator	z	51°	56°	62°	69°	76°
	$r(k)$ ±	0″.43	0″.34	0″.31	0″.30	0″.33

Beyond 70° the computation ought not to be extended, as the formula for $r(\delta)$ cannot be relied upon beyond the limits of the observations from which it was deduced, but the computation as it stands shows that the probable error of a determination of k passes through a minimum for a value of the angle of the prism, differing but little from 60°. It should, however, be borne in mind that the above values of $r(k)$ cannot be considered as the probable errors of a determination of k; they are simply a series of numbers supposed to be proportional to the probable errors.

From this discussion we conclude that the use of a 60° prism for a determination of the constant of aberration is to be recommended, on the ground that the results are free from systematic error, arising from deformation of the prism between the times of observation, and that the effect of accidental errors of observation is approximately a minimum for this value of the angle. The maximum of simplicity is also secured by this choice of an angle, since a complete determination of the constant can be obtained from each pair of stars observed, while by the methods hitherto proposed two pairs of stars must be combined in order to eliminate the effect of possible variations in the angle of the prism.

Washburn Observatory, Madison, 1887 *December* 2.

OBSERVATIONS OF *X CYGNI*. 7437

$20^h\ 37^m\ 43^s + 35°\ 3'.6$ (1855).

BY S. C. CHANDLER, JR.

The following are all the maxima and minima of this star which my observations afford to the present time. The epochs are numbered from the maximum occurring nearest the date of discovery. The times of maximum and minimum phases have been determined both by single curve drawings, and by reference to a mean light-curve formed from all the observations. Those here given result from the latter method, although it is doubtful whether, in this case, there is any reason for preference, as the star distinctly belongs to the class whose light-curves are not constant in different periods. Its brightness at minimum, especially, is notably variable, sometimes falling not quite to the star d, at other times a half-magnitude below it. The bright and faint minima do not alternate regularly, so that the star does not belong to the β *Lyræ* type.

E	Observed Maxima.			Observed Minima.		
	Camb. M.T.	O—C	p	Camb. M.T.	O—C	p
	1886 d	d		1886 d	d	
3	Nov. 28.3	—0.9	1	Nov. 25.0	+2.3	½
4	Dec. 13.7	—1.1	1	Dec. 8.6	+0.5	1
5	1887 31.9	+1.5	1	1887 25.0	—1.3	1
6	Jan. 16.1	+1.1	½	Jan. 11.3	+0.8	1
22	Sept. 21.2	—0.4	½			
23	Oct. 7.4	+0.2	1			
24	22.7	—0.1	1	Oct. 15.3	—0.3	1
25	Nov. 8.3	+0.9	1	31.1	—1.7	1
26	23.7	+0.7	1	Nov. 16.9	—0.5	1
27				Dec. 4.3	+1.3	1

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The most satisfactory elements yet found are

1886 Oct. 13^d 14^h 20^m Greenw. M.T. +15^d 14^h 24^m E.

Approximate duration of increase,		5.6 days.
" "	decrease,	10.0 "

The comparison with these elements is given in the column (O—C).

The comparison-stars used, are

	1855.0 α	1855.0 δ	L
	h m s	° ′	
a	20 23 48	+35 58.5	15
b	20 36 43	34 56.4	10
d	20 34 16	34 52.5	7
f	20 35 9	34 31.4	6

where the values of *L* are of a very provisional character. The maximum brilliancy of the variable is ordinarily about 6^M.4; the minimum brilliancy ranges from 7^M.2 to 7^M.7.

Cambridge, 1887 *December* 9.

OBSERVATIONS OF THE TWO HUNDRED SEVENTY-FIRST ASTEROID,

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6 INCH EQUATORIAL,

BY PROF. EDGAR FRISBY.

(Communicated by the Superintendent.)

1887 Washington M.T.		*	No. Comp.	Planet — * Δα	Planet — * Δδ	Planet's apparent α	Planet's apparent δ	log *p* Δ for α	log *p* Δ for δ
	h m s			m s	′ ″	h m s	° ′ ″	s	″
Oct. 21	9 48 55.2	1	20 , 3	+1 59.26	−0 18.2	1 8 25.39	+11 40 55.4	*n*9.187	0.612
22	9 29 38.6	1	17 , 4	+1 12.41	—4 15.5	1 7 38.55	+11 36 58.1	*n*9.269	0.617

Mean Place for 1887.0 of Comparison-Star.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 6 23.13	+3.00	+11 40 57.1	+16.5	Grant 287

ERRORS IN SHORTREDE'S LOGARITHM-TABLES.

To those who use SHORTREDE's tables of logarithm sines, tangents, etc., it may be useful to know of the following typographical errors found:

Page 27. In table of Prop. parts, under 17′ 50″.2, for 196 read 186.
Page 535. cos 39° 47′ 37″, for 3619 read 5619.

The latter error was discovered and reported to the Coast Survey Office, and to Prof. GEORGE DAVIDSON in January, 1870; also to the London publishers. The former has lately been found,— both by

JAMES S. LAWSON, *Asst. C. and G. Survey.*

San Francisco, Cal., 1887 *November* 25.

CORRIGENDA IN No. 163.

Page 146.	Eq. 3,	second term, transfer r''^2 from denominator to numerator.
147.	" 13,	fourth line, first term, read $\cos(2n't-2n''t-\omega'+\omega'')$.
"	" "	second line, the numerators of all but the first of the inferior indices should be 5.
"	" 16,	third line, the numerators of all the inferior indices should be 7.
148.	" 17,	first line, for *mr* put $m''r^2$.
"	" 23,	second line, second term, for n'' put A_2 in the coefficient.

CONTENTS.

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THE

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MERIDIAN OBSERVATIONS OF MISCELLANEOUS STARS AT THE DUDLEY OBSERVATORY,

BY H. V. EGBERT.

The following list is composed largely of stars used for comparison with the comet 1882 I (Wells), such having been selected, in general, as were too faint to be included in the observing lists of the A. G. Zones. Others were used with the comets 1884 I and II, 1885 II, and 1886 I. A few were observed by request for the Cincinnati Observatory, and at the close are added three observations of the temporary star in the nebula of *Andromeda*. For stars of less declination than +42° 40′, the chronograph was used, while for those of greater declination the eye-and-ear method was employed. The stars of the *Berliner Jahrbuch* have been used as fundamental.

No.	DM. Mag.	No. Obs.	A.R. 1885.0.	prec.	Dec. 1885.0.	prec.	Epoch 1880 +	DM.	No.
			h m s	s	° ′ ″	″		°	
1	8.5	6	0 15 52.02	3.403	+74 25 43.9	+20.01	5.40	+74	8
2	9.0	4	0 34 25.44	3.773	74 3 20.5	19.83	4.89	73	29
3	9.4	2	0 39 45.43	3.161	20 59 20.5	19.75	6.46	20	99
4	7.3	2	0 40 39.76	3.163	20 59 45.2	19.74	6.45	20	103
5	9.1	3	0 47 30.54	4.037	+74 5 6.9	19.62	4.89	+73	45
6	7.5	3	1 8 41.57	3.033	— 5 39 8.9	19.16	5.04	— 5	215
7	9.4	2	1 49 19.83	4.949	+71 53 21.4	17.81	4.95	+71	112
8	7.3	3	2 3 52.51	2.820	—20 6 54.6	17.19	5.99	—20	404
9	8.8	2	2 20 14.35	5.171	+69 53 50.6	16.42	4 97	+69	150
10	9.4	2	2 24 20.99	5.209	69 45 50.8	16.21	5.01	69	159
11	9.0	3	2 27 36.03	5.229	+69 35 4.8	16.04	4.97	+69	166
12	7.9	3	2 30 42.12	2.812	—17 38 50.9	15.87	5.99	—17	502
13	8.9	2	2 35 57.78	5.244	+68 49 29.3	15.59	4.97	+68	191
14	9.3	2	2 53 21.68	5.250	67 8 57.9	14.58	5.01	67	238
15	9.1	3	2 56 39.48	5.298	67 17 16.0	14.40	4.99	67	243
16	8.8	3	2 59 58.38	5.261	+66 38 43.4	14.19	4.97	+66	245
17	6.7	3	3 10 3.70	2.703	—20 26 47.6	13.54	5.99	—20	605
18	8.2	1	3 25 55.13	3.204	+ 7 10 28.0	12.49	6.06	+ 7	517
19	9.5	2	3 53 50.42	4.894	+57 58 31.8	10.49	5.05	+57	766
20	6.4	3	4 1 27.64	2.687	—18 21 39.6	9.92	6.10	—18	752
21	9.1	2	4 23 42.16	4.369	+46 44 0.5	8.18	5.09	+46	893
22	8.1	2	4 30 19.04	4.214	+42 44 6.8	7.65	5.09	+42	1015
23	7.3	3	4 45 41.17	2.634	—19 5 48.2	+ 6.39	6.10	—19	1023
24	8.5	2	6 12 26.06	2.541	—21 42 5.4	— 1.09	5.16	—21	1410
25	8.1	2	7 2 31.96	3.432	+15 36 44.5	5.40	5.21	+15	1482
26	8.8	2	7 27 16.86	3.407	15 5 4.6	7.45	5.21	15	1601
27	8.5	2	7 43 28.78	3.394	14 58 53.2	8.75	5.21	15	1673
28	9.5	2	7 54 51.61	3.380	14 40 36.9	9.63	5.21	14	1806
29	8.8	2	7 59 40.30	3.374	+14 34 40.0	10.00	5.21	+14	1822
30	8.2	2	8 3 49.65	2.624	—21 21 54.0	—10.32	5.24	—21	2290

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No.	DM. Mag.	No. Obs.	A.R. 1885.0.	prec.	Dec. 1885.0.	prec.	Epoch 1880 +	DM.	No.
			h m s	s	° ′ ″	″		°	
31	9.5	2	8 16 28.60	3.352	+14 9 55.3	−11.25	5.21	+14	1882
32		2	8 49 14.42	3.308	13 25 37.6	13.50	5.26		Anon
33	7.5	2	8 53 7.53	3.306	13 31 12.6	13.75	5.26	13	2021
34	9.0	2	9 4 31.12	3.287	13 1 21.5	14.46	5.26	13	2050
35	8.5	2	9 14 42.08	3.267	12 26 44.2	15.06	5.26	12	2021
36	8.0	2	9 30 9.62	3.244	11 56 46.5	15.92	5.26	12	2067
37	7.0	2	9 41 15.01	3.236	12 5 58.3	16.49	5.26	12	2095
38	9.1	2	9 47 17.31	3.221	+11 30 28.6	16.78	5.28	+11	2120
39	6.0	3	9 49 11.95	2.782	−21 56 41.0	16.88	5.29	−21	2935
40	9.0	2	9 52 20.44	3.209	+10 58 18.6	17.02	5.28	+11	2138
41	7.0	2	10 1 42.17	2.823	−20 41 43.4	17.44	5.29	−20	3104
42	9.3	2	10 34 23.13	3.154	+ 9 30 14.0	18.67	5.30	+ 9	2384
43	9.3	2	10 36 47.89	3.150	9 16 46.7	18.75	5.30	9	2395
44		2	10 40 45.20	3.145	9 7 54.6	18.87	5.31		Anon
45	9.3	2	10 41 56.47	3.143	8 57 50.3	18.90	5.30	9	2409
46	8.3	3	10 46 25.20	3.138	8 49 24.1	19.03	5.29	8	2423
47	9.2	2	10 50 39.92	3.134	8 43 20.1	19.14	5.29	8	2436
48	9.2	2	10 51 30.29	3.132	8 38 37.0	19.16	5.30	8	2437
49	8.2	2	10 57 42.55	3.124	8 12 6.3	19.32	5.30	8	2452
50	9.5	2	10 58 31.94	3.125	8 26 27.4	19.34	5.29	8	2454
51	9.0	2	11 0 9.47	3.121	7 56 41.8	19.37	5.30	8	2456
52	9.4	2	11 8 44.28	3.112	7 30 44.8	19.55	5.29	7	2427
53	9.1	2	11 9 16.16	3.112	7 39 44.9	19.56	5.30	7	2429
54		2	11 19 53.08	3.102	7 8 7.8	19.75	5.29		Anon
55	9.5	2	11 22 48.09	3.099	6 55 15.7	19.79	5.29	7	2451
56	8.9	2	11 38 24.65	3.086	6 4 21.4	19.96	5.29	6	2490
57	8.8	2	11 54 21.99	3.075	5 16 23.4	20.05	5.29	5	2568
58	9.2	2	12 2 34.02	3.071	4 31 54.0	20.05	5.29	4	2577
59	9.2	2	16 29 51.22	1.036	+58 45 54.0	7.69	5.46	+58	1647
60	9.4	2	16 58 4.07	3.323	−10 59 6.0	5.35	5.57	−10	4435
61	9.0	2	17 4 55.00	3.300	9 57 23.6	4.77	5.55	9	4510
62	8.5	2	17 6 38.91	3.315	10 32 43.1	4.63	5.57	10	4456
63	9.0	2	17 10 2.96	3.236	7 8 2.4	4.34	5.54	7	4415
64	7.0	2	17 19 48.66	3.222	6 28 42.4	3.50	5.54	6	4592
65	8.9	2	17 19 59.63	3.195	5 18 56.5	3.48	5.54	5	4444
66	8.5	2	17 22 34.32	3.200	− 5 32 36.7	3.26	5.54	− 5	4449
67	9.3	2	17 59 54.26	2.153	+34 31 5.4	− 0.01	5.61	+34	3108
68	8.9	2	18 2 44.96	2.058	37 11 1.1	+ 0.24	5.61	37	3018
69	8.8	2	18 3 5.90	2.090	36 18 57.8	0.27	5.61	36	3020
70	8.7	2	18 5 20.58	2.099	36 3 57.2	0.47	5.61	36	3035
71	7.7	2	18 7 52.74	2.034	37 51 37.8	0.69	5.61	37	3041
72	6.0	3	18 9 14.65	2.001	38 44 31.1	0.81	5.63	38	3113
73	9.5	2	18 12 21.08	1.988	39 5 46.7	1.08	5.61	39	3370
74	9.4	2	18 13 45.74	1.962	39 45 35.4	1.20	5.61	39	3374
75	9.3	2	18 15 49.94	1.927	40 39 45.6	1.38	5.61	40	3342
76	9.1	3	18 20 2.62	1.876	41 56 12.4	1.75	5.61	41	3041
77	7.8	4	18 25 46.87	1.751	44 50 23.2	2.25	5.66	44	2909
78	8.8	2	18 27 16.24	1.772	44 24 13.4	2.38	6.61	44	2913
79	6.8	4	18 29 3.76	1.730	45 41 19.0	2.54	5.70	45	2736
80		3	18 29 18.22	1.754	44 49 34.7	2.56	5.67		Anon
81	9.5	3	18 31 55.82	1.719	45 38 20.6	2.78	5.64	45	2743
82	9.4	2	18 32 21.88	1.722	45 34 34.2	2.82	5.69	45	2744
83		2	18 32 44.80	1.681	46 25 40.8	2.86	5.68		Anon
84	8.0	3	18 33 55.79	1.723	45 34 21.3	2.96	5.72	45	2747
85	9.4	2	18 34 25.56	1.682	46 27 0.0	3.00	5.70	46	2517
86	8.8	2	18 34 33.94	1.691	+46 15 29.1	+ 3.01	5.71	+46	2518

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No.	DM. Mag.	No. Obs.	A.R. 1885.0.	prec.	Dec. 1885.0.	prec.	Epoch 1880+	DM.	No.
			h m s	s	° ′ ″	″		°	
87	9.4	2	18 36 13.02	1.678	+46 33 26.4	+ 3.16	5.66	+46	2524
88	9.5	3	18 36 54.89	1.646	47 13 26.7	3.22	5.68	47	2674
89	9.1	2	18 37 7.81	1.646	47 13 53.3	3.23	5.64	47	2675
90	8.8	2	18 37 55.60	1.642	47 19 51.3	3.30	5.70	47	2677
91	9.3	2	18 40 41.47	1.602	48 10 5.4	3.54	5.66	48	2753
92	9.3	1	18 40 46.19	1.600	48 12 38.1	3.55	5.62	48	2754
93	9.1	2	18 40 56.90	1.604	48 8 3.2	3.56	5.68	48	2755
94	9.1	4	18 41 1.24	1.607	48 4 39.3	3.57	5.69	48	2756
95	6.3	3	18 44 39.78	1.566	48 56 46.6	3.88	5.68	48	2767
96	8.3	2	18 45 11.54	1.526	49 42 45.3	3.93	5.64	49	2872
97	9.0	2	18 45 57.26	1.514	49 57 11.3	3.99	5.65	49	2874
98	8.5	3	18 48 40.71	1.418	51 41 25.1	4.23	5.65	51	2440
99	9.5	3	18 52 1.50	1.410	51 55 3.9	4.51	5.65	51	2458
100	7.3	3	18 54 19.52	1.435	51 34 2.0	4.71	5.68	51	2464
101	8.2	2	18 54 44.90	1.299	53 46 48.4	4.74	5.64	53	2157
102	8.5	1	18 58 14.78	1.318	53 35 13.6	5.04	5.62	53	2167
103		1	18 58 58.23	1.281	54 11 20.5	5.08	5.64		Anon
104	9.1	2	19 0 6.90	1.325	53 31 55.7	5.20	5.64	53	2173
105	7.5	7	19 1 27.50	1.284	54 13 0.0	5.31	5.68	54	2080
106	9.4	3	19 4 5.02	1.260	54 39 42.0	5.41	5.63	54	2086
107	8.5	6	19 4 37.42	1.291	54 12 30.4	5.58	5.70	54	2087
108	8.9	3	19 5 55.99	1.264	54 39 39.2	5.69	5.63	54	2088
109	5.3	4	19 11 51.98	1.076	57 30 25.5	6.19	5.68	57	1968
110	9.4	2	19 15 40.48	1.093	57 25 35.3	6.50	5.63	57	1976
111	8.2	3	19 23 17.06	0.948	59 32 22.6	7.13	5.64	59	2030
112	7.7	3	19 26 48.35	0.962	59 31 28.3	7.42	5.71	59	2038
113	8.3	3	19 27 49.92	1.060	58 21 53.3	7.50	5.67	58	1925
114		3	19 32 6.94	0.879	60 42 30.0	7.84	5.65		Anon
115	9.0	5	19 33 58.56	0.825	61 22 58.2	7.99	5.69	61	1882
116	8.4	2	19 41 55.45	0.754	62 30 11.4	8.63	5.63	62	1750
117		1	19 49 36.22	0.669	63 43 0.8	9.23	5.62		Anon
118	9.3	5	19 49 47.77	0.675	63 40 13.4	9.24	5.68	63	1569
119	9.0	2	19 58 32.60	0.592	64 53 49.2	9.92	5.64	64	1402
120	8.7	4	20 13 15.74	0.476	66 43 17.5	11.01	5.68	66	1278
121	9.4	3	20 17 25.56	0.486	66 53 21.2	11.32	5.66	66	1283
122	9.0	3	20 19 15.92	0.479	67 3 55.0	11.45	5.69	66	1285
123	9.5	2	20 21 10.81	0.400	67 47 31.9	11.59	5.67	67	1242
124	8.5	2	20 32 31.28	0.408	68 27 32.0	12.38	5.72	68	1137
125		2	20 36 40.30	0.387	68 53 34.3	12.67	5.72		Anon
126	9.5	2	20 48 23.04	0.372	69 49 36.5	13.44	5.72	69	1132
127	9.5	2	20 52 12.02	0.402	69 54 28.1	13.69	5.73	69	1135
128	7.5	2	20 53 30.91	0.473	69 30 23.4	13.77	5.72	69	1136
129	9.5	4	21 55 19.69	0.777	73 13 30.7	17.16	5.10	73	950
130	9.5	3	22 34 30.95	1.359	74 7 54.2	18.67	5.17	73	984
131	8.3	4	22 35 40.37	1.407	73 53 50.5	18.71	5.09	73	985
132	7.0	6	23 24 27.05	2.323	+74 35 31.8	19.81	5.89	+74	1022
133	8.7	2	23 38 40.28	3.085	— 5 38 43.9	19.97	4.98	— 5	6041
134	8.2	2	23 41 57.94	3.083	— 5 52 41.0	19.99	4.98	— 6	6293
135	6.3	4	23 46 48.74	2.787	+74 54 11.9	20.02	5.90	+74	1047
136		4	23 47 56.60	2.815	74 44 12.1	20.03	5.11		Anon
137	8.8	2	23 58 17.16	3.036	+74 47 46.9	20.05	5.74	+74	1059
	var.		0 36 26.66	3.254	+40 38 14.7	+19.80	5.712		
			26.69		13.8		5.715		
			26.70		13.5		5.717		

Dudley Observatory, 1887 *December*.

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ON THE NEW VARIABLE *U ORIONIS.* 2100

$5^h\ 47^m\ 13^s\ +20°\ 8'.8$ (1855.0.)

By EDWIN F. SAWYER.

This long-period variable, discovered by GORE, in 1885, has recently passed through another, although very faint, maximum.

The star was first seen on November 17, and found 5+ steps < DM. 20°,1171, or about $8^M.7$. The increase of light must have been very rapid, for at the next opportunity of observing the star, which occurred on November 29, it was found 4 steps > DM. 20°,1171 and 5 steps < DM. 19°,1106, or $7^M.5$. The light remained apparently stationary from November 29 to January 2, 1888, a period of 34 days. A careful inspection of the light-curve, assigns a maximum for about December 14. The strong moonlight, which prevailed near maximum, precludes a sharp determination of this phase, although the time as determined cannot be more than a day or two out of the way. The observations of last year and this would indicate a period of almost exactly one year. At its maximum this year, the star was about one magnitude fainter than last year.

The star is very slowly decreasing, and is now 5+ steps < DM. 19°,1106 and 2 steps > DM. 20°,1171, or about $7^M.7$. The following are the light-values observed on each evening:

			Light.				Light.
1887	Nov.	17	3.2	1887	Dec.	22	11.2*
	"	29	11.2*		"	23	11.2*
	Dec.	3	11.2*	1888	Jan.	2	11.2:
	"	5	11.2		"	3	10.9
	"	6	11.2		"	5	10.9
	"	12	11.2		"	11	10.2
	"	13	11.2		"	16	9.9
	"	16	11.2				

* = Moonlight.

Cambridgeport, 1888 *January* 16.

The need of a definite notation for this well-established variable is such that, in the absence of any systematic arrangement of the nomenclature since the publication of SCHÖNFELD's catalogue, it is denoted here by the letter *U*. The letter *T* is left for assignment, hereafter, to some one of the other three unnamed stars in *Orion*, whose variability seems beyond question, although their periods are yet undetermined. — G.

THE MOTION OF *HYPERION.*

By PROF. A. HALL.

In the *Comptes Rendus de l'Académie des Sciences*, Aug. 30, 1886, M. TISSERAND has given an ingenious transformation of the formulas of the *Mécanique Céleste*, *Livre II*, No. 50, for the case where the motions of two planets or satellites, P and P', are nearly commensurable. The result he obtains is as follows: *If the motion of P' was at first circular and uniform, the perturbations caused by the planet P would have for their principal effect the transformation of this motion into one that would be very nearly an elliptic Keplerian motion, with a uniform rotation of the major axis.* The two satellites of *Saturn*, *Titan* and *Hyperion*, furnish an example of the case considered by M. TISSERAND. But since his formulas are a transformation of those given by LAPLACE, which I have applied (*Monthly Notices*, *R.A.S.*, XLIV, p. 364), the result ought to be the same if the secular terms and those depending on the eccentricities are omitted. I have, therefore, recomputed the terms independent of the eccentricity, by the formulas:

$$\frac{\delta r}{a} = \frac{m'n^2}{2}\sum\frac{a^2\,\dfrac{\partial A^{(i)}}{\partial a}+\dfrac{2n}{n-n'}\,aA^{(i)}}{i^2(n-n')^2-n^2}\cos i(l'-l)$$

$$\delta v = \frac{m'}{2}\sum\left[\frac{n^2}{i(n-n')^2}aA^{(i)}+\frac{2n^3\left(a^2\dfrac{\partial A^{(i)}}{\partial a}+\dfrac{2n}{n-n'}\,aA^{(i)}\right)}{i(n-n')\left[i^2(n-n')^2-n^2\right]}\right]\sin i(l'-l)$$

where l, l', n, n' are the mean longitudes and mean motions of the satellites. By assuming that the coefficients of $3(l-l')$ result from the action of *Titan* alone, the apparent eccentricity found by observation gives the mass of *Titan*

$$m = \frac{1}{10765},$$

the mass of *Saturn* being unity. Hence the expression for

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the radius vector and true longitude of *Hyperion* are as follows:

$$r' = a' \left[1 - 0.00043 \cos(l-l') - 0.00141 \cos 2(l-l') + 0.09967 \cos 3(l-l') \right.$$
$$\left. + 0.00078 \cos 4(l-l') + 0.00022 \cos 5(l-l')\right]$$
$$v' = l' + 0^\circ.160 \sin(l-l') + 0^\circ.222 \sin 2(l-l') - 11^\circ.396 \sin 3(l-l')$$
$$- 0^\circ.072 \sin 4(l-l') - 0^\circ.018 \sin 5(l-l')$$

These coefficients agree nearly with those given by Tisserand. If we infer the mass of *Hyperion* from that of *Titan* by means of their relative magnitudes, we have for the mass of this satellite,

$$m = \frac{1}{4162150}$$

The largest terms in the motion of *Titan* produced by *Hyperion* would be therefore,

$$\delta r = -0.00025 \cos 4(l'-l)$$
$$\delta v = -0^\circ.038 \sin 4(l'-l)$$

In order to test this theory the longitude of *Hyperion* has been carried forward from 1852, the epoch of Lassell's observations, assuming the mean motion I have given before, the terms in $3(l-l')$ only have been applied, and Lieut. Allen has compared with the observations made at Malta in 1864, and with those made at Washington in 1886. It happens that the nine angles observed at Malta are fairly well represented. In the case of the more complete observations at Washington the residuals show that other terms must be considered; but for such an imperfect theory the result is good, and it seems possible by this simple method to make a tolerable ephemeris of this satellite. By this method of considering the question the eccentricity of the orbit of *Hyperion* is nearly destroyed. The residuals of 1886 would give an eccentricity less than 0.02, but from such a theory nothing definite can be inferred concerning this element. The next step would be to introduce the term depending on the eccentricity of the orbit of *Titan*.

Washington, 1888 *January* 25.

ON THE PERIOD OF *ALGOL*. 1090

By S. C. Chandler, Jr.

Somewhat more than a century has elapsed since the recognition by Goodricke of the character of this star's variation. During this interval about fifty astronomers have taken part in its observation, and nearly seven hundred minima have been recorded. Various investigations have been made, from time to time, upon the fluctuations to which the period of the star is subject; and, principally, as the result of the labors of Argelander and Schönfeld, their general character has been pretty closely ascertained. The law according to which they proceed, however, has not yet been successfully developed, and Argelander was of the opinion that the search for the mathematical form of its expression must be long postponed, until sufficient light is thrown upon the matter by later observation. Nearly twenty years have passed since this was written, and now, although the watch upon the minima of recent years has unfortunately been somewhat relaxed, it seems worth while to renew the attempt to discover the law in question. The effort has now greater chance of success, because meanwhile Schönfeld's classical memoir on the light-curve of *Algol* has appeared, affording the means for reducing homogeneously a large portion of the data anew, a condition essential to justify the expectation of advancing our present knowledge. The results of this endeavor will be given in the following pages, and appear to be reasonably satisfactory. The apparently highly complicated anomalies in the period are amenable to a comparatively simple law, more closely than I had dared to hope. This law comprises two inequalities —the first having a period, rather uncertainly determined, of 141.3 years and a coefficient of 173.3 minutes of time, and the second a period of 37.7 years and a coefficient of 18.0 minutes. There is also evidence of a third irregularity, with a cycle of 17 years, but its coefficient of only 3.5 minutes brings its range so nearly within the limits of the observation-errors, that its existence must await further verification.

Before proceeding to the account of the collection and treatment of the material which forms the basis of the present investigation, it is proper to recite briefly the results of previous writers. The first of any importance was that of Wurm, who, from 50 or 60 minima, recorded by various observers between 1783 and 1818, deduced by least squares the value of the period, $2^d\ 20^h\ 48^m\ 58^s.50$. Comparing this with his determination from sixteen months' observations, twenty years previous, namely $2^d\ 10^h\ 48^m\ 58^s.69$, he does not undertake to distinguish whether, in the interval, the period has really changed. The diminution which his calculations seem to indicate, however, was put beyond all possible doubt by Argelander, who first demonstrated its existence, as well as the fact that the shortening was not proportional to the time, at least down to about the middle of the present century. Argelander's attempts to develop the constants in a formula, either with secular or periodical

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terms, proved fruitless, owing to the insufficiency of the data. Constructing five normal epochs from all the observed minima, he represented them exactly by the expressions,

$$79865^{d}\ 10^{h}\ 14^{m}\ 38^{s}.3 \quad +2^{d}\ 20^{h}\ 48^{m}\ 58^{s}.77376\, p$$
$$+0^{s}.000\,085\,200\,8\ p^{2}$$
$$-0.000\,000\,060\,863\,3\ p^{3}$$
$$-0.000\,000\,000\,016\,121\ p^{4}$$

$$79865^{d}\ 9^{h}\ 25^{m}\ 13^{s}.6 \quad +2^{d}\ 20^{h}\ 48^{m}\ 57^{s}.8773\, p$$
$$-30^{m}\ 57^{s}.8\ \sin(392''.04786\ p)$$
$$+49\ \ 24.7\ \cos(392.04786\ p)$$

where $p = -2377$. But these formulas do not conform to the observations intermediate or subsequent to the normal epochs.

The calculations of Schönfeld on the period of *Algol*, in the memoir referred to, relate merely to the interval comprised by his own series of observations from 1853 to 1870; his object being only a satisfactory representation of the minima within those limits, to serve as a basis for uniting them in a general light-curve. For this purpose he finds, as the most satisfactory elements,

$$\begin{aligned} &1860 \text{ June } 14^{d}\ 3^{h}\ 24^{m}.11 \text{ (Paris M.T.)}\\ &+2^{d}\ 20^{h}\ 48^{m}.89308(E-7700)\\ &+0.000\,006\,120\,4(E-7700)^{2}\\ (b)\quad &-0.000\,000\,002\,034\,9(E-7700)^{3}\end{aligned}$$

the last term of which, however, is much less than its probable error. But he finds that the opera-glass series, which is alone used for the light-curve, and which extends from 1859 to 1870, is equally well represented by a uniform period, in the elements,

$$\begin{aligned} &1867 \text{ January } 0^{d}\ 11^{h}\ 1^{m}.2 \text{ (Paris M.T.)}\\ (c)\quad &+2^{d}\ 20^{h}\ 48^{m}.9(E-8534)\end{aligned}$$

The elements in the *Zweiter Catalog* differ slightly from these, being derived from 51 minima observed by Schönfeld between 1864 Dec. 27, and 1873 Nov. 13, inclusive. It may be added that very shortly after this the period, which for fifteen years had been nearly constant, if not very slowly lengthening, began again to diminish rapidly, and afterwards has again become sensibly constant.

Two or three other papers on the subject have appeared of late years, but they add nothing to what had been already established by Argelander and Schönfeld, are superficial in their mode of treatment, and require no special mention here.

In undertaking a general discussion of the period of *Algol* at the present time, no step forward can be taken without special consideration of the methods by which the times of minimum, as published by the various observers, were obtained; for the determination of this or any other phase which can be taken as a reckoning-point in a variable star is influenced not only by personal differences of observation, as are all other sorts of astronomical measurement, but also by a source of individual difference from which these are free, namely, that arising from the arbitrary nature of the processes of reduction, not to be avoided in the present low stand-point of our knowledge. Indeed, there is reason to believe that these reduction-errors so overshadow the observation-errors, that, the former being eliminated, the effect of the latter will be comparatively unimportant. Fortunately this elimination can be easily attained when we possess the original observations. While, therefore, I have endeavored to collect all the minima that have been published to date, and have presented them in this paper with their deviations from the elements finally deduced, the elements themselves have been founded solely upon those series of observations for which the original comparisons have been published, or which, from knowledge otherwise derived, we can bring to a uniform system with these by an appropriate homogeneous reduction.

Probably the best way of finding the period of a variable of the *Algol* type, from series of observations by various individuals, would be, so long as we do not know the absolute form of its light-curve, to abandon the use of the minimum phase as a reference point, and to take, instead, the mean between the times when the star attains a given brightness before and after minimum. A period so determined would be independent of assumption as to the form of the light-curve, and free from most of the sources of individual constant error, physiological or psychological, which are likely to occur, either in Argelander's method, or in any suitable photometric observation. But such a method has practical disadvantages and limitations in application to existing data; and I decided, therefore, to sacrifice some of its rigor, by the following procedure.

For each minimum the comparisons of the variable with each comparison-star were arranged in pairs, corresponding to nearly equal brightness before and after minimum. The mean time for each pair was then corrected for the effect of the small difference of brightness, if any, and also by the reduction required to give the instant of minimum by Schönfeld's light-curve, adopted as a standard. The resultant times were then weighted according to the velocity of the light-variation, and the means taken, first for the comparisons with each star, and finally for all the stars, as the time of minimum. The elements for effecting these reductions have been given by Schönfeld on page 93 of the 36th *Jahresbericht des Mannheimer Vereins für Naturkunde*, with such explanation as makes further description of the method here superfluous. Instead of single pairs of comparisons, it was often convenient, especially to avoid differences of brightness of more than a few tenths of a step, to form combinations of unequal numbers on opposite sides of minimum; the weights, of course, being properly modified.

In this manner the times of minima have been recomputed from the original observations of Goodricke, Argelander,

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OUDEMANS, VAN DER VEN, SCHOTT, FLAGG, LINDEMANN, SAWYER, REED, and myself, and of SCHÖNFELD previous to 1859, his observations since that date having already been reduced by him in the same manner. To the 197 minima, thus uniformly treated, were added, after reference to the same system as hereafter described, the 49 minima determined by WURM, and the 250 by SCHMIDT, making in all 496 minima employed in the investigation of the period. Besides these I have collected 199 minima by other observers, but could not employ them, as the originals are not available, nor any information as to how the published times were obtained, from which we can infer the amount of the systematic reduction to SCHÖNFELD's zero.

With this general explanation, I proceed to remark upon the reduction of the separate series.

The valuable data of GOODRICKE have never been fully utilized. His times of minima seem to rest entirely upon the comparisons very near minimum, generally on those with ρ *Persei* alone; and ARGELANDER has adopted them in most cases without change, in others with an alteration of five minutes. The series comprises 96 observations, involving 136 comparisons, in which there are

	39	comparisons with ρ *Persei*
	26	" " ε "
	22	" " δ "
	14	" " ζ "
	4	" " γ "
	13	" " β *Trianguli*
	10	" " β *Arietis*
	8	" " γ *Andromedae*
Total	136	

The times were changed from apparent to mean York time, and the verbal descriptions of differences of brightness were numerically converted by means of the following equivalents, adopted after careful scrutiny.

Rather a little	= 1 step,	Somewhat	= 2 steps
Rather	" "	Not quite	" "
Nearly equal	" "	A little	" "
A very little	" "	Certainly	3 "
Less	2 steps,	Evidently	" "
Brighter	" "	Considerably	4 "
Not so	" "	Much	5 "

Giving half weight to the minima of 1783 Jan. 17, Feb. 23, Feb. 26, April 13, and Nov. 17, the mean epoch is —2120, for which SCHÖNFELD's elements (c) give 1783 May $12^d\ 8^h\ 0^m.6$ Paris M.T.; with which and the period $2^d\ 20^h\ 48^m\ 58^s.7$, comparison was made with all the observed times corrected for longitude and the light-equation. The resulting intervals from computed minimum (O—C), with the corresponding differences from each comparison-star, numerically converted as above, were arranged in order, and combined in pairs taken before and after minimum; whence was computed the normal time of minimum by SCHÖNFELD's table. Thus we have:

	(O—C)	Wt.
	h m	
From δ *Persei*	—8 39.4	70
" ε "	—8 34.1	116
" ζ "	—8 49.8	66
" β *Trianguli*	—8 35.6	58
" β *Arietis*	—9 0.3	21
Mean (O—C)	—8 40.2	

which is the correction to SCHÖNFELD's elements (c) for epoch —2120, by GOODRICKE's comparisons with other stars than ρ *Persei*, which cannot be here used, on account of its variability.

The time has also been calculated of each minimum independently, after reducing the observations by the following scale:

$$c = 24 \qquad \zeta = 11$$
$$h = 17 \qquad \varepsilon = 11$$
$$b = 12 \qquad \gamma = 10$$
$$\delta = 8$$

where, according to the established notation, $c = \gamma$ *Andromedae*, $h = \beta$ *Arietis*, $b = \beta$ *Trianguli*, and the Greek letters indicate stars in *Perseus*. This scale is practically identical with SCHÖNFELD's, except for ε and b. From GOODRICKE's descriptions it is plain that to his eye these stars were nearly equal, the former perhaps a trifle fainter; while SCHÖNFELD makes ε 3.7 b. In the table below, column I gives the observed York mean times of minima from the comparisons with other stars than ρ, and column II the times found by means of ρ alone.

GOODRICKE'S MINIMA.

Epoch.	1783	I	II	Mean	Wt.	(O—C)	Corr. (Argel.)
		h m	h m	h m		m	m
—2161	Jan. 14	9 33	9 30:	9 32		—526.3	+ 2.3
2160	17	6 25		6 25	½	522.5	
2155	31	14 2:	14 29	14 18		535.8	—11.0
2153	Feb. 6	8 6	8 10	8 8		524.4	— 1.5
2147	23	12 19	12 39	12 29	½	559.1	— 9.6
2146	26		9 43	9 43	½	534.4	— 0.2
2138	Mar 21	8 22	8 32	8 27		524.3	— 5.2
2131	Apr. 10	9 56	10 1:	9 58		537.4	— 3.2
2130	13	7 6		7 6	½	518.5	
2086	Aug. 17	10 55:	11 14	11 8		501.2	— 5.6
2062	Oct. 25	6 11:	6 34	6 26		509.7	— 8.2
2056	Nov. 11	11 18:	11 9	11 12		516.8	+ 2.7
2055	14	8 15	8 20	8 17		500.7	— 2.8
—2054	17	4 30	4 52	4 41	½	—525.6	—11.0
—2120	Mean					—522.3	

The column (O—C) is the deviation from SCHÖNFELD's elements, and the last column, the correction to be applied to

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the times assumed by ARGELANDER, (BB. VII, 347) to get the values given by this new reduction.

The results of the two modes of computation above outlined agree within $2^m.1$. The first value, $-520^m.2$, is the one hereafter employed in the derivation of the period.

The fact that these observations precede, by nearly three quarters of a century, any others from which a knowledge of the light-curve can be derived, lends a certain interest to the following comparison of the curve which they furnish, with that of SCHÖNFELD. Each value is the mean of five observations.

Interval from Min.	Light-Steps. GOODRICKE	SCHÖNFELD	G—S
h m			
—3 1	17.7	18.7	—1.0
2 14	13.3	16.3	—3.0
—1 41	12.4	13.2	—0.8
—1 16	10.2	10.3	—0.1
0 49	8.3	7.4	+0.9
+0 14	7.2	5.9	+1.3
0 51	7.4	7.2	+0.2
1 18	9.9	8.8	+1.1
1 39	11.5	10.8	+0.7
1 59	12.7	13.0	—0.3
2 19	14.8	14.9	—0.1
+3 5	18.4	17.8	+0.6

The decrease is somewhat less rapid, relatively to the increase, with GOODRICKE than with SCHÖNFELD. Little stress, however, can be placed on conclusions from so small a body of material.

(*To be continued.*)

TWO HUNDRED SEVENTY-SECOND ASTEROID.

A planet of the 13th magnitude was discovered by CHARLOIS at Nice,

Feb. 4.4808 Greenwich M.T. $\alpha = 10^h\ 1^m\ 10^s.8$ $\delta = +19°\ 20'\ 22''$ Daily motion, -52^s in α, and 5′ northward.

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CORRIGENDUM.

No. 160, p. 126, July 9. Second α, for $17^h\ 11^m\ 41^s.16$, put $17^h\ 11^m\ 42^s.16$.

NOTICE.

Mr. FRANK MULLER of the Leander McCormick Observatory, at the University of Virginia, desires to give notice that he purposes computing a definitive orbit for the comet 1887 IV (*Barnard, May* 12), and asks that any yet unpublished observations of this comet be made public as soon as possible.

CONTENTS.

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THE

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ON THE PERIOD OF *ALGOL*.

BY S. C. CHANDLER, JR.

(*Continued.*)

In the interval between GOODRICKE and ARGELANDER nineteen observers made nearly one hundred determinations of minima, one-half of which, however, were contributed by WURM alone. The chronological distribution is very unequal, four-fifths being anterior to 1800, the rest scattered sparsely over the remaining forty years. The difficulty which this introduces into our problem is increased by the fact that, with one or two exceptions, we possess neither the details of the observations nor any information as to the manner in which the published times were deduced. Fortunately, in the case of WURM's series, by far the most important in number and extent, we find here and there in the writings of that zealous and careful observer evidence of sharp discrimination as to the phase assumed as the true minimum, and indications of his mode of arriving at it sufficient to guide us to a safe estimate of the reduction to the zero-point adopted in this discussion. He repeatedly refers to this phase as "the middle of the duration of least brightness," which duration he at first estimates as 20 or 25 minutes, afterwards as 18 minutes. He regards it as a distinctly defined phase which, with practice, can be easily recognized. He insists, however, that a good determination of minimum requires several hours; recommends that the times be noted of *Algol's* equality before and after minimum with neighboring stars, such as γ and δ *Persei*; and adds, that "the mean of these times gives also the middle of the smallest light." According to SCHÖNFELD's light-table, equality with γ occurs $1^h\ 21^m$ before and $1^h\ 40^m$ after true minimum, and with δ $0^h\ 54^m$ before and $1^h\ 4^m$ after; whence the mean of the times of equality with these stars is later by $9^m.5$ and $5^m.0$, respectively, than the instant of minimum in SCHÖNFELD's curve. The extreme difference which can thus arise from want of symmetry in the light-curve is $12^m.3$, at about five hours from minimum. Although we do not know the distribution of WURM's comparisons with respect to the minimum, it is safe to infer that his times need a negative correction of several minutes. This inference is supported by the fact that a systematic difference of this sort actually appears between his observations and GOODRICKE's. Thus, if we refer all of WURM's times back to GOODRICKE's mean epoch —2120, by means of the period $2^d\ 20^h\ 48^m\ 58^s.7$, we have for the differences of the yearly means:

Year	No.	GOODRICKE–WURM.
		m
1783	4	—27.6
1784	7	—15.1
1785	3	—14.0
1786	1	—15.9
1787	1	—10.1
1788	3	—13.6
Mean	19	—17.1

Weighing all the facts, I decided to apply the correction $-7^m.0$ to all of WURM's times to reduce them to the adopted zero.

ARGELANDER's observations, extending from 1840 to 1859, with single minima in 1862 and 1866, in all 64 minima, are contained in the seventh volume of the *Bonn Observations*, the original comparisons on pp. 418–426, the corresponding times of minima on pp. 348–349. Little is there said of the method of calculation, except that the times were found separately from each comparison-star and the mean of all taken. But SCHÖNFELD's recollection (*V. J. S.*, V, 113), from personal intercourse, accords with ARGELANDER's more explicit statement in the *Astronomical Journal* (IV, 58), that he used "all the observations made for half an hour before and after minimum, by taking the mean of the times at which *Algol* manifested the same difference of brightness from the comparison-stars during its decrease and increase of brilliancy, and then the mean of all these means as the final result."

I have recomputed the whole series strictly in accordance with the principles heretofore laid down. The resulting times and weights for the separate stars are too voluminous for production here, but the final Paris heliocentric times of minima will be found in the table hereafter given, with the corrections to ARGELANDER's values. As was to be expected, the minus sign generally prevails. The mean of all the corrections is $-5^m.5$.

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In the same table of observed minima will be found the results of my reduction of the observations of OUDEMANS, in his *Zweijährige Beobachtungen;* of VAN DER VEN, in the *Astronomische Nachrichten* (XLV, 219); of SCHOTT, FLAGG, and MASTERMAN, in various places in the *Astronomical Journal;* of SCHÖNFELD's from 1853 to 1859, in the *Sitzungsberichte of the Vienna Academy* (XLII, 182–189); of LINDEMANN, in the *Bulletins of the St. Petersburg Academy* (XX, 387); and of SAWYER and REED, kindly communicated in manuscript. The average of the corrections which these new values assign to the times given by the observers themselves, are:

Observer.	No.	Corr.
		m
OUDEMANS	10	—4.6
V. D. VEN	6	—1.9
SCHOTT	6	—1.1
MASTERMAN	19	—1.0
FLAGG	4	—0.6
SCHÖNFELD	15	—1.0
LINDEMANN	5	—8.3

OUDEMANS's mode of reduction was the same as ARGELANDER's. Three additional minima by him (*A. N.*, XLV, 117) have dates following so closely upon the series in the *Zweij. Beobb.*, that I felt justified in assuming for them the correction —4^m.6 given by the other ten. But I have not thought it proper to make a similar assumption for an additional minimum of LINDEMANN's series, to be found in the *Moscow Bulletin* (LIV, 123).

Although SCHMIDT's original observations are not available, we have an entirely satisfactory mode of securing homogeneity with the adopted system, by direct comparison with the series of ARGELANDER and SCHÖNFELD; SCHMIDT's series overlapping the former through two-thirds of its extent, and the latter entirely. I have made such comparisons in two or three ways, by appropriately combining the data in the table of yearly mean epochs to be presently given. One of these determinations is as follows:

	ARGEL.-SCHMIDT	Wt.	SCHÖN.-SCHMIDT	Wt.
	m		m	
	—6.9	3.9	— 4.3	4.2
	4.7	3.5	6.6	2.8
	4.8	3.7	9.6	2.6
	3.3	2.8	10.9	3.6
	0.7	6.4	1.1	8.2
	—6.3	5.2	6.3	3.7
			3.6	6.0
			2.9	6.2
			— 1.2	9.6
Brute means	—4.5		— 5.2	
Weighted "	—4.2		— 3.9	

We have another method of estimating the element in question. Comparing SCHMIDT's light-curve (*A.N.* XXXIX, 82ff) with SCHÖNFELD's, we have the intervals before and after minimum corresponding to the points of equality with three of the comparison-stars, as shown in the following table, from whence come the corrections, in the last column, to reduce SCHMIDT's to SCHÖNFELD's minimum.

	SCHMIDT			SCHÖNFELD			
	Before	After	Mean	Before	After	Mean	Diff.
	m	m	m	m	m	m	m
δ	—46.7	+48.0	+0.65	—53.0	+63.5	+5.25	— 4.6
ε	64.0	61.0	—1.50	96.1	116.6	10.25	—11.8
b	—95.0	+96.0	+0.50	—65.9	+82.1	+8.10	— 7.6

For points nearer minimum the correction would be proportionally less.

I finally adopted the systematic correction —5^m.0, to be applied to all of SCHMIDT's times of minimum, to reduce them to SCHÖNFELD's zero.

It should be added, that for SCHMIDT's observations before 1875, the data of his revised list (*A. N.*, LXXXVII, 195), have been employed.

The minima, thus reduced and corrected, were now referred to the sun and the meridian of Paris, were compared with SCHÖNFELD's elements (*c*), and then assembled in yearly means, not by calendar years, but according to successive conjunctions with the sun, whence the accompanying table of "yearly mean epochs," in which the fifth column, O—C′, is the resulting correction to SCHÖNFELD's elements. The weights in the sixth column were assigned on the basis of 0.5 for a single observation of GOODRICKE, WURM, or SCHMIDT; of 1.5 for one of SCHÖNFELD; and of 1.0 for the others. MASTERMAN's series has been omitted, after an independent examination ending in a conclusion like that of of ARGELANDER and SCHÖNFELD, that the extraordinary internal agreement of the observations requires either the assignment of a relative weight so high as virtually to exclude all other contemporaneous series, or their own exclusion on the ground of mental preoccupation.

In the endeavor to represent algebraically the series (O—C′), I first satisfied myself that its expression according to powers of the epoch was impracticable, without the introduction of terms of an inconvenient order. Through successive approximation, I finally rested upon the following trigonometrical series:

$$
\begin{aligned}
C—C' = —293^{m}.0 + 0^{m}.02375\,E &+ 173^{m}.3 \sin(\tfrac{1}{50}E + 338^{\circ}.3) \\
&+ 18.0 \sin(\tfrac{3}{40}E + 82.5) \\
&+ 3.5 \sin(\tfrac{1}{6}E + 22.0)
\end{aligned}
$$

whose numerical values subtracted from O—C′ give the residuals O—C, in the last column of the table. The calculation of the constants was actually conducted upon the twenty-six normal epochs given on page 172, which can easily be reproduced upon inspection.

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Table of Yearly Mean Epochs.

Obs.	No.	Mean Date.	Mean Epochs.	O—C′	Wt.	O—C
Gk	14	1783.4	— 2120	—520.2	7	— 5.1
Wm	4	1783.9	2056	—494.7	2.0	+16.2
"	7	1784.8	1936	—497.7	3.5	+ 5.0
"	3	1785.8	1807	—488.8	1.5	+ 4.7
"	1	1786.7	1701	—478.5	0.5	+ 7.4
"	1	1787.9	1536	—471.4	0.5	+ 2.3
"	3	1788.9	1414	—460.0	1.5	+ 4.5
"	6	1790.2	1254	—451.5	3	+ 0.5
"	1	1790.8	1173	—430.2	0.5	+15.7
"	2	1792.0	1026	—425.5	1	+ 8.4
"	2	1793.7	800	—425.4	1	—11.1
"	3	1795.7	542	—387.9	1.5	+ 2.4
"	1	1796.7	427	—380.1	0.5	— 0.9
"	4	1798.0	250	—374.0	2	—12.2
"	2	1799.0	— 121	—368.4	1	—19.1
"	1	1803.2	+ 410	—317.7	0.5	—14.0
"	1	1813.9	1767	—232.3	0.5	— 9.4
"	1	1814.9	1896	—203.8	0.5	+ 9.7
"	1	1815.7	2001	—201.7	0.5	+ 3.9
"	2	1817.9	2276	—184.8	1	— 0.9
"	1	1818.7	2385	—176.7	0.5	— 1.5
"	1	1823.7	3018	—141.5	0.5	—15.3
"	1	1825.8	3282	—126.2	0.5	—20.4
A	3	1840.2	5116	+ 12.6	3	— 5.7
"	7	1841.0	5212	+ 14.3	7	— 5.4
"	3	1841.7	5312	+ 28.8	3	+ 8.1
"	3	1842.9	5462	+ 32.6	3	+11.3
"	2	1843.9	5589	+ 28.9	2	+ 7.5
"	1	1845.8	5837	+ 25.7	1	+ 4.8
Sm	2	1846.6	5939	+ 26.4	1	+ 5.9
A	1	1846.7	5950	+ 12.9	1	— 7.6
Sm	7	1847.9	6104	+ 22.3	3.5	+ 2.2
A	5	1848.0	6109	+ 16.2	5	— 3.8
Sm	7	1849.7	6339	+ 18.8	3.5	— 0.5
A	1	1850.1	6379	+ 4.0	1	—15.1
Sm	3	1851.0	6499	+ 22.3	1.5	+ 3.9
A	1	1851.2	6515	+ 42.7:	0.5	+24.4
Sm	2	1852.1	6628	+ 4.1	1	—13.3
A	3	1852.2	6646	+ 15.2	3	— 2.1
Sm	3	1852.9	6733	+ 28.8	1.5	+12.5
"	5	1853.9	6860	+ 4.0	2.5	—10.7
A	7	1853.9	6868	+ 8.5	7	— 6.1
Sd	2	1854.0	6876	+ 21.4	3	+ 6.9
Od	2	1854.0	6877	+ 14.3	2	— 0.2
Sd	6	1854.8	6980	+ 10.4	9	— 2.5
A	7	1854.9	6988	+ 14.0	7	+ 1.3
Od	6	1854.9	6990	+ 22.4	6	+ 9.7
V	6	1855.0	7001	+ 15.9	6	+ 3.4
Sm	1	1855.1	7013	+ 5.2	0.5	— 7.1
St	1	1855.2	7026	+ 13.7	1	+ 1.6
Sd	1	1855.7	7094	+ 14.0	1.5	+ 3.2
Sm	3	1855.9	7123	+ 12.7	1.5	+ 2.4
A	2	1856.1	7140	+ 6.3	2	— 3.7
Od	2	1856.1	7145	+ 7.4	2	— 2.5
"	3	1856.8	7238	+ 3.9	3	— 4.2
A	2	1856.8	7238	+ 9.9	2	+ 1.8
Sd	4	1856.9	7246	+ 6,8	6	— 1.1
F	4	1857.0	7246	+ 9.5	4	+ 1.6
St	2	1857.0	7247	+ 5.0	2	— 2.9
Sm	3	1857.1	+ 7266	+ 7.0	1.5	— 0.5

Obs.	No.	Mean Date.	Mean Epochs.	O—C′	Wt.	O—C
Sd	1	1857.7	+ 7343	+ 3.2	1.5	— 2.8
Sm	12	1858.0	7382	+ 3.7	6	— 1.5
A	9	1858.0	7384	+ 8.5	9	+ 3.3
St	2	1858.1	7403	— 4.5	2	— 9.3
"	1	1858.8	7486	— 0.2	1	— 3.4
Sd	1	1858.8	7487	+ 2.2	1.5	— 1.0
A	2	1858.8	7490	+ 12.9	2	+ 9.7
Sm	6	1858.9	7507	+ 4.2	3	+ 1.3
Sd	1	1859.5	7584	— 7.5	1.5	— 9.1
A	3	1859.7	7610	— 4.7	3	— 5.9
Sm	12	1859.8	7620	— 2.1	6	— 3.1
Sd	1	1860.7	7735	— 0.3	1.5	+ 0.1
Sm	15	1860.9	7750	+ 5.5	7.5	+ 6.1
Sd	3	1862.0	7892	— 6.1	4.5	— 4.3
Sm	8	1862.0	7894	— 1.3	4	+ 0.5
A	1	1862.2	7924	— 9.2	1	— 7.2
Sm	5	1863.7	8118	+ 6.2	2.5	+ 8.3
Sm	7	1864.7	8244	— 9.2	3.5	— 7.5
Sd	2	1865.0	8293	— 0.2	3	+ 1.2
Sm	6	1865.8	8385	— 1.6	3	— 0.7
Sd	10	1865.9	8391	+ 2.2	15	+ 3.0
A	1	1866.1	8422	— 8.0	1	— 7.4
Sm	10	1866.8	8513	+ 0.4	5	+ 0.5
Sd	3	1867.0	8532	— 6.2	4.5	— 6.2
Sm	4	1867.8	8631	— 2.9	2	— 3.4
Sd	2	1868.0	8663	+ 4.9	3	+ 4.3
Sm	11	1868.9	8780	0.0	5.5	— 0.7
Sd	1	1869.3	8821	+ 7.0	1.5	+ 6.4
Sm	4	1869.6	8864	— 1.9	2	— 2.3
Sd	9	1869.9	8903	+ 0.2	13.5	0.0
Ln	1	1870.7	9009	— 17.3	1	—16.4
Sd	6	1870.9	9027	— 3.2	9	— 2.1
Sm	7	1871.0	9036	— 4.7	3.5	— 3.5
"	7	1871.8	9142	— 5.6	3.5	— 2.7
Sd	5	1871.9	9160	— 2.7	7.5	+ 0.8
"	7	1872.8	9267	— 2.9	10.5	+ 3.2
Sm	12	1872.8	9268	— 9.2	6	— 3.1
Ln	1	1872.8	9272	— 17.3	1	—11.0
"	2	1873.9	9405	— 10.0	2	+ 0.4
Sm	10	1873.9	9405	— 8.1	5	+ 2.3
Sd	6	1874.0	9426	— 5.2	9	+ 6.0
Ln	1	1874.8	9522	— 12.4	1	+ 2.4
Sd	4	1874.8	9531	— 8.0	6	+ 7.2
Ch	1	1875.7	9640	— 26.5	1	— 6.7
Sm	11	1875.8	9662	— 19.6	5.5	+ 1.2
"	11	1876.8	9777	— 29.4	5.5	— 3.3
"	8	1877.8	9911	— 50.1	4	—17.5
"	7	1878.9	10051	— 28.7	3.5	+10.8
"	6	1879.9	10182	— 48.3	3	— 2.3
"	9	1880.8	10292	— 33.9	4.5	+17.4
"	9	1881.9	10426	— 64.2	4.5	— 6.4
"	5	1883.0	10568	— 67.1	2.5	— 2.6
"	8	1883.8	10670	— 75.8	4	— 6.4
Sr	1	1884.9	10816	— 76.7	1	— 0.5
"	1	1886.0	10952	— 96.0	1	—13.0
Ch	1	1886.9	11072	— 81.6	1	+ 7.8
"	2	1887.9	11196	—104.5	2	— 8.5
Rd	2	1887.9	11196	—100.2	2	— 4.2
Sr	1	1887.9	+11200	— 99.5	1	— 3.3

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TABLE OF NORMAL EPOCHS.

Mean Epoch.	Wt.	O—C′	Corr. Epoch and Period.	v_1	First sine term	v	Second sine term.	v_3	Third sine term.	O—C v_4
		m	m	m	m	m	m	m	m	m
— 2058.2	12.5	—509.8	—341.9	—167.9	—154.2	—13.7	—17.1	+ 3.4	+2.2	+ 1.2
— 1612.5	4.0	—474.6	—331.3	—143.3	—140.1	— 3.2	—11.1	+ 7.9	+3.2	+ 4.7
— 1194.3	4.5	—443.4	—321.3	—122.1	—123.8	+ 1.7	— 2.2	+ 3.9	—0.2	+ 4.1
— 608.8	3.0	—399.1	—307.4	— 91.7	— 96.6	+ 4.9	+10.8	— 5.9	—3.4	— 2.5
— 118.9	3.5	—364.4	—295.8	— 68.6	— 70.7	+ 2.1	+17.2	—15.1	+0.1	—15.2
+ 2100.2	3.0	—197.4	—243.1	+ 45.7	+ 60.1	—14.4	—15.6	+ 1.2	+0.7	+ 0.5
3150.0	1.0	—133.8	—218.2	+ 84.4	+114.4	—30.0	—11.8	—18.2	—0.4	—17.8
5212.9	13.0	+ 17.3	—169.2	+186.5	+171.8	+14.7	+16.5	— 1.8	+0.6	— 2.4
5512.8	5.0	+ 31.1	—162.1	+193.2	+173.2	+20.0	+12.5	+ 7.5	—2.3	+ 9.8
6055.2	11.5	+ 19.6	—149.2	+168.8	+171.0	— 2.2	+ 1.1	— 3.3	—2.6	— 0.7
6486.4	10.5	+ 16.6	—139.0	+155.6	+164.8	— 9.2	— 8.7	— 0.5	+1.4	— 1.9
6856.7	16.0	+ 12.8	—130.2	+143.0	+156.5	—13.5	—15.1	+ 1.6	+3.5	— 1.9
7019.2	36.5	+ 13.8	—126.3	+140.1	+152.0	—11.9	—16.8	+ 4.9	+3.2	+ 1.7
7252.9	20.0	+ 6.8	—120.7	+127.5	+144.7	—17.2	—17.9	+ 0.7	+1.7	— 1.0
7477.1	35.0	+ 2.7	—115.4	+118.1	+136.9	—18.8	—17.5	— 1.3	—0.5	— 0.8
7823.9	18.5	— 0.1	—107.2	+107.1	+123.0	—15.9	—13.9	— 2.0	—3.2	+ 1.2
8225.3	9.0	— 1.9	— 97.7	+ 95.8	+104.8	— 9.0	— 6.3	— 2.7	—2.5	— 0.2
8435.1	28.5	— 0.2	— 92.7	+ 92.5	+ 94.4	— 1.9	— 1.6	— 0.3	—0.7	+ 0.4
8825.1	27.5	+ 0.7	— 83.4	+ 84.1	+ 73.8	+10.3	+ 7.4	+ 2.9	+2.8	+ 0.1
9084.7	24.5	— 4.2	— 77.2	+ 73.0	+ 59.2	+13.8	+12.5	+ 1.3	+3.5	— 2.2
9267.6	17.5	— 5.9	— 72.9	+ 67.0	+ 48.8	+18.2	+15.2	+ 3.0	+2.8	+ 0.2
9451.2	23.0	— 7.3	— 68.5	+ 61.2	+ 38.1	+23.1	+17.2	+ 6.1	+1.3	+ 4.8
9712.9	12.0	— 24.7	— 62.3	+ 37.6	+ 22.4	+15.2	+18.0	— 2.8	—1.2	— 1.6
10035.1	10.5	— 42.5	— 54.7	+ 12.2	+ 3.0	+ 9.2	+16.3	— 7.1	—3.4	— 3.7
10473.0	15.5	— 58.9	— 44.2	— 14.7	— 23.5	+ 8.8	+ 9.5	— 0.7	—1.8	+ 1.1
+11103.0	8.0	— 95.4	— 29.3	— 66.1	— 60.3	— 5.8	— 4.7	— 1.1	+3.3	— 4.4

In order that the evidence of the reality of the periodical terms may be conveniently inspected, I place in the column "Corr. Epoch and Period" the values of the first two terms of the equation, and in the sixth, eighth and tenth columns, the values of the sine terms; then the various series of residuals, v_1, v_2, v_3, v_4, left outstanding by their successive elimination, by subtraction from the preceding column. The comparison of each sine term with the column of residuals immediately preceding it, will furnish the criterion of its genuineness. Such a comparison will, I think, leave little doubt of the reality of the first and second sine terms. The third, however, is of an order which will need careful observation to verify; although I have felt warranted in employing it, not only because it breaks up the systematic character of the signs in v_3, and reduces the sum $[pv_3v_3] = 5206$ to $[pv_4v_4] = 3156$, but also because a special examination of the series of ARGELANDER, SCHÖNFELD, and SCHMIDT, has shown that all three independently manifest its existence, the first two very distinctly.

Adding the value C—C′ to SCHÖNFELD's elements (c), and bringing up to the beginning of 1888 by putting $E' = E - 11210$, we have,

$$\text{1888 Jan. } 3^d\,7^h\,30^m\,50^s.25 \text{ (Paris M.T.)} + 2^d\,20^h\,48^m\,55^s.425\,E'$$
$$+\,173^m.3 \sin(\tfrac{1}{80}E' + 202^\circ\,30')$$
$$+\,18.0 \sin(\tfrac{3}{40}E' + 203\;15)$$
$$+\,3.5 \sin(\tfrac{1}{8}E' + 90\;20)$$

From the above elements the value of the period is

$$p = 2^d\,20^h\,48^m\,55^s.425 + 3^s.6296 \sin(111^\circ.7 - \tfrac{1}{80}E)$$
$$+\,1.4137 \sin(\;7.5 - \tfrac{3}{40}E)$$
$$+\,0.6109 \sin(\;68.0 - \tfrac{1}{8}E)$$

The interpretation of the theory thus presented is somewhat as follows. The period of the time of GOODRICKE's discovery was $2^d\,20^h\,48^m\,58^s.0$. It lengthened to $59^s.8$ in 1798, then shortened to $57^s.2$ in 1808, and again lengthened, irregularly, to $59^s.2$ in 1830. Shortly after began a rapid diminution, at the rate of half a second annually, to $54^s.0$ in 1843. After a halt and slower diminution to $52^s.8$ in 1858, an increase set in of a second and a half, to $54^s.4$ in 1866; from which point the period again fell rapidly to $51^s.1$ in 1877, and has since remained nearly constant. Should the theory prove to be approximately correct, we are now nearly at the end of the prolonged interval of general decrease, and may expect in a few years the beginning of an increase, which, with halts and retrogressions, should march to a maximum somewhere late in the next century. We must, however, wait until this general interval of increase has well begun before the value of the cyclical coefficient of the first sine term in the above formula can be found with accuracy.

The accompanying "Table of Observed Minima" is a collection of all the observations I have been able to find. The epochs are reckoned, according to established usage, from Jan. 1, 1800. The "Reduction to Sd." is the correction

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corresponding to the new reduction, heretofore described. The "Reduction to ⊙," carefully assigned, is given for all minima except those of SCHMIDT, whose revised table is expressed directly in heliocentric time. The addition of these two reductions and of the longitude in the appended table, to the local time published in the original authority, indicated in the last two columns, with the help of the annexed indexes to abbreviations of observers' names and references, gives the heliocentric Paris M.T. of observed minimum, in the fourth column. The values O—C are the comparisons with the elements of this paper. It should be noted, however, that the corrections —7^m.0 and —5^m.0 have been applied to the times in the fourth column for WURM's and SCHMIDT's minima, respectively, before taking these residuals. The column p is supplied principally in behalf of SCHMIDT's observations; and the weights, when given, have reference only to the minima of any observer *inter se*.

To the very complete collection of ARGELANDER (BB.VII), of observations before 1840, I have added only three by LALANDE, two each by GOODRICKE and WURM, and one each by LUTHMER and BODE. A few of these were probably intentionally omitted, others accidentally. The data were independently compiled from original authorities. HARDING's and WIESEN's *kleinen Ephemeriden* (1832, p. 100) not being accessible, I took WURM's last eleven minima from ARGELANDER's list; as also one of LALANDE's (*E*—238), the source of which has escaped me.

INDEX TO OBSERVERS.

Abbr.	Observer	No. Min.	Abbr.	Observer	No. Min.
A	Argelander	64	Ly	Lindley	2
Bl	Bessel	2	Lm	Loomis	10
Bd	Bode	2	Lt	Luthmer	7
Bn	Bruhns	10	Ms	Masterman	37
Br	Bruhl (Graf)	1	My	Mayer	1
Cm	Camerer	1	Mc	Méchain	1
Ch	Chandler	4	Ml	Mitchell	11
En	Englefield	2	Nl	Nell	4
F	Flagg	4	Ol	Olbers	1
Gl	Glasenapp	5	Od	Oudemans	13
Gk	Goodricke	6	Pn	Penrose	2
Hd	Harding	3	Pg	Pigott	3
Hg	Hartwig	2	Rd	Reed	2
HC	Harv. Coll. Obs.	7	RM	Ricque de Monchy	6
Hs	Heis	5	R	Rome (Anon)	1
Hn	Hennekeler	2	Sr	Sawyer	3
JH	Herschel, J.	2	Sm	Schmidt	250
WH	Herschel, W.	2	Sd	Schönfeld	75
Hk	Hoek	6	St	Schott	6
Hb	Huber	2	T	Tiele	2
Km	Kam	5	V	van der Ven	6
Kh	Koch	1	Wn	Winnecke	18
Kl	Köhler	2	Wl	Wurlisch	4
Kr	Krüger	6	Wm	Wurm	49
Ll	Lalande	12			
Ln	Lindemann	6		Total number of minima	684
Ln	" (phot.)	6			

INDEX TO REFERENCES.

Abbr.	Authority	Vol.	Page	Abbr.	Authority	Vol.	Page
A1	Ast. Nachr.	39	291	C1	Conn. d. Temp.	1792	287
A2	" "	45	105	C2	" "	1801	481
A3	" "	45	219	D	Bonner Beobb.	7	347
A4	" "	45	317	E	Mem. de l'Acad.		
A5	" "	45	117		Montpellier	3	429
A6	" "	47	257	F	Bull. Moscow	54	116
A7	" "	48	235	G	Greenw. Obs.	2	309
A8	" "	51	383	H1	Harding & Wies.	1832	100
A9	" "	53	264	H2	" "	1833	95
A10	" "	54	132	J1	Ast. Journal	5	6
A11	" "	66	271	J2	" "	5	29
A12	" "	73	3	J3	" "	5	37
A13	" "	78	9	J4	" "	5	93
A14	" "	80	147	J5	" "	5	105
A15	" "	83	359	J6	" "	5	123
A16	" "	87	7	J7	" "	5	140
A17	" "	87	195	J8	" "	5	175
A18	" "	61	281	J9	" "	6	44
A19	" "	88	234	J10	" "	6	83
A20	" "	89	98	J11	" "	6	96
A21	" "	89	155	J12	" "	6	187
A22	" "	91	379	K	Sill. Journal	1863	145
A23	" "	94	101	L	Am. Asso. Adv.		
A24	" "	96	257		Science	1866	7
A25	" "	99	225	M	Mann. Jahresb.	36	95
A26	" "	101	311	N	Bull. Met. Roma	4	10
A27	" "	104	289	O	Zweij. Beobb.		26
A28	" "	108	131	P1	Phil. Trans.	1783	474
B1	Bode's Jahrb.	1786	244	P2	" "	1784	290
B2	" "	1787	145	P3	" "	178[illegible]	1
B3	" "	1788	184	P4	" "	[illegible]	27[illegible]
B4	" "	1788	237	R1	Mem. R.A.S.	[illegible]	[illegible]
B5	" "	1789	175	R2	M. Not. R.A.S.	30	179
B6	" "	1801	155	S	Bull. Ac. St. P.	20	387
B7	" "	1792	253	T	Mém. Ac. Paris	1788	241
B8	" "	1796	177	U	Proc. Am. Ac.	1880	378
B9	" "	2 Sup.	108	V1	VJS. Astr. Ges.	1881	80
B10	" "	1796	238	V2	" "	1885	158
B11	" "	1823	196	W	Sitzb. Wien. Ak.	44	574
B12	" "	1824	243	Z	Zach, Mon. Corr.	2	77

LONGITUDES FROM PARIS.

Place	Longitude h m	Place	Longitude h m
Athens	—1 25.6	Mannheim	—0 24.5
Basle	—0 21.0	Montpellier	—0 6.3
Berlin	—0 44.2	Münster	—0 21.2
Bonn	—0 19.0	Nantucket	+4 49.8
Bremen	—0 25.9	New York	+5 5.3
Cambridge	+4 53.8	Olmütz	—0 59 7
Carlsruhe	—0 24.2	Pulkowa	—1 52.0
Dantzig	—1 5.3	Rome	—0 40.6
Dresden	—0 45.6	Slough	+0 11.7
Göttingen	—0 30.4	Tübingen	—0 26.9
Greenwich	+0 9.3	Utrecht	—0 11.2
Hanover	—0 29.6	Washington	+5 17.5
Highclere	+0 14.6	Weld, Maine	+4 50.9
Hoya	—0 27.2	Wimbledon	+0 10.2
Leyden	—0 8.6	York	+0 13.8
London	+0 9.7		

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TABLE OF OBSERVED MINIMA.

E	Reduction to Sd.	Reduction to ⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1782 d h m		m		
— 2183		+7.6	Nov. 12 8 35.9		+ 35.1	Gk	P1
2167		+5.4	Dec. 28 5 51.4		+ 47.1	"	"
			1783				
2161	+ 2.3	+3.6	Jan. 14 9 49.4		— 8.6	"	"
2160		+3.3	17 6 42.1:		— 4.9	"	"
2155	—11.0	+1.5	31 14 33.3		— 18.5	"	"
2153	— 1.5	+0.7	Feb. 6 8 22.5		— 7.2	"	"
2147	— 9.6	—1.6	23 12 41.2:		— 42.2	"	"
2146	— 0.2	—2.0	26 9 54.8:		— 17.6	"	"
2138	— 5.2	—4.7	Mar. 21 8 36.1		— 8.1	"	"
2131	— 3.2	—6.5	Apr. 10 10 5.3		— 21.6	"	"
2130		—6.7	13 7 13.1:		— 2.8	"	"
2123		—7.6	May 3 9 4.1		+ 5.5	WH	B1
2110		—7.0	June 9 14 32.7		— 62.5	En	P3
2102		—5.2	July 2 13 49.5		— 17.4	"	"
2093		—2.8	28 10 31.0		+ 63.4	Ly	G
2086		+0.2	Aug. 17 11 0.2		— 10.0	Mc	B2
"		+0.2	17 11 16.3		+ 6.1	My	D
"	— 5.6	+0.2	17 11 22.0		+ 11.8	Gk	P2
2078		+3.1	Sept. 9 9 52.5		+ 10.4	Ly	G
2071		+5.3	29 11 32.0		+ 7.2	WH*	B3
"		+5.3	29 11 24.7		— 0.1	Kl	B4
			1783				
2063		+6.8	Oct. 22 10 5.0		+ 1.5	Wm	B5
2062		+7.1	25 7 10.3		+ 17.8	"	"
"	— 8.2	+7.1	25 6 47.1		+ 1.6	Gk	P2
2056	+ [illegible]7	+7.6	Nov. 11 11 33.4		— 5.9	"	"
205[illegible]	[illegible]	+7.6	14 8 38.4		+ 10.2	"	"
[illegible]	—11.0	+7.6	17 5 2.4:		— 14.8	"	"
[illegible]		+7.6	17 5 40.8		+ 16.6	Wm	B5
2046		+6.8	Dec. 10 4 25.0		+ 29.0	"	"
			1784				
1966		—2.5	July 26 13 12.6		+ 6.2	Cm	D
1957		+0.6	Aug. 21 8 33.8		— 0.3	Wm	B5
1951		+2.8	Sept. 7 13 28.0		0.0	"	"
1950		+3.1	10 10 18.3		+ 1.4	"	"
1949		+3.5	13 7 11.7		+ 5.8	"	"
1943		+5.5	30 11 48.1		— 4.6	Br	B3
1927		+7.6	Nov. 15 9 15.8		+ 12.5	Wm	B5
1926		+7.5	18 6 10.7		+ 18.5	"	"
			1785				
1889		—2.6	Mar. 4 8 0.6		— 3.5	"	"
1845		—4.6	July 8 12 3.9		+ 12.0	Pg	P4
1837		—1.9	31 10 7.8		— 15.8	"	"
1823		+3.0	Sept. 9 14 3.2		+ 7.0	Wm	B5
1822		+3.5	12 10 44.7		— 0.5	"	"
"		+3.5	12 10 58.1		+ 19.9	Pg	P4
			1786				
1776		+2.7	Jan. 22 8 25.9		+ 8.0	Wm	B5
1701		+1.2	Aug. 25 9 38.2		+ 7.4	"	B6
1536		+6.8	Dec. 11 12 13.8		+ 2.3	"	"
			1788				
1430		+6.2	Oct. 10 10 53.2		+ 17.4	Ll	T
1422		+7.4	Nov. 2 8 41.4		— 26.2	"	"
"		+7.4	2 9 15.4		+ 0.8	Wm	B6
"		+7.4	2 8 43.2		— 24.4	Bd	B7
1421		+7.5	5 5 47.3:		— 9.3	"	"
— 1415		+7.5	22 10 42.5		— 8.0	Ll	T

E	Reduction to Sd.	Reduction to ⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1788 d h m		m		
— 1414		+7.5	25 7 43.4		+ 4.0	Ll	T
"		+7.4	25 7 54.4		+ 8.0	Wm	B6
1406		+6.3	Dec. 18 6 23.3		+ 5.0	"	"
			1790				
1271		+4.1	Jan. 9 9 12.1		+ 49.0	Ll	T
"		+4.1	9 8 28.1		— 2.0	Wm	B6
1263		+1.3	Feb. 1 7 26.3		+ 31.4	Ll	T
1257		—1.0	18 11 49.0		— 6.8	Wm	B6
1256		—1.4	21 8 38.6		— 6.2	"	"
"		—1.4	21 9 38.6		+ 60.8	Ll	T
1249		—3.9	Mar. 13 10 42.1		+ 14.5	Wm	B6
1248		—4.1	16 7 16.9		+ 0.3	"	"
1241		—6.2	Apr. 5 9 3.8		+ 4.3	"	"
1173		+6.7	Oct. 17 8 45.7		+ 15.7	"	"
1151		+6.2	Dec. 19 10 40.6		+ 20.0	Kl	B8
			1791				
1052		+5.3	Sept 29 7 29.8		+ 12.5	Wm	B6
			1792				
1000		—1.8	Feb. 25 9 48.2		+ 4.3	"	"
			1793				
804		+3.2	Sept. 9 9 30.2		— 15.1	"	B9
"		+3.2	9 9 29.2	omit	— 9.1	Ll	B6
"		+3.2	9 9 42.9		+ 4.6	Kh	B10
797		+5.3	29 11 21.3	omit	— 6.9	Wm	B9
			1795				
548		+3.6	Sept 13 10 55.6		+ 8.1	"	B6
547		+3.9	16 7 44.9		+ 8.5	"	"
532		+7.3	Oct. 29 7 42.3		— 9.2	"	"
			1796				
427		+1.2	Aug. 25 9 35.2		— 0.9	"	"
			1797				
366		—0.7	Feb. 16 7 10.3		— 7.7	Ll	C2
291		+4.3	Sept 19 8 36.3		— 3.6	Wm	B6
			1798				
247		+2.4	Jan. 23 12 25.4		— 10.4	"	"
239		—0.6	Feb. 15 10 47.4		— 20.3	"	"
238		—0.9	18 7 54.1		+ 4.3	Ll	D
231		—3.5	Mar. 10 9 26.5		— 6.2	"	C2
223		—5.9	Apr. 2 7 57.1		— 14.6	Wm	B6
147		+7.4	Nov. 6 5 54.5		— 21.0	"	H1
			1799				
— 95		—6.2	Apr. 4 8 26.0		— 17.3	"	"
			1800				
+ 18		—1.4	Feb. 22 9 23.6		+ 31.1	Ll	Z
			1803				
410		—4.8	Mar. 23 8 46.9		— 14.0	Wm	H1
			1805				
727		+4.0	Sept 17 7 44.1		+ 8.0	Bl	A1
742		+7.3	Oct. 30 7 47.4		— 3.0	"	"
			1808				
1103		—1.8	Aug. 30 9 52.8		— 29.9	Hb	A7
			1809				
1224		—0.5	Aug. 12 9 38.5		+ 35.1	"	"
			1813				
1767		+7.6	Nov. 16 8 9.6		— 9.4	Wm	H1
			1814				
+ 1896		+7.5	Nov. 21 5 46.2		+ 9.7	"	"

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E	Reduction to Sd.	⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1815 d h m		m		
2001		+4.0	Sept 18 7 22.8		+ 3.9	Wm	H1
			1817				
2272		+7.4	Nov. 3 8 30.8		— 1.4	"	"
"		+7.4	3 8 35.3		+ 10.1	Hd	D
2280		+7.4	26 7 3.7		— 0.3	Wm	H1
			1818				
2385		+4.6	Sept 23 8 45.4		— 1.5	"	"
			1819				
2482		—5.8	June 28 11 32.6		— 18.4	Lt	B11
2513		+4.8	Sept 25 9 26.2		+ 16.9	"	"
2521		+6.7	Oct. 18 8 0.1		+ 19.0	"	"
2528		+7.5	Nov. 7 9 43.9		+ 19.9	"	"
			1820				
2574		—4.3	Mar. 18 6 52.1		— 4.9	"	"
2626		—0.3	Aug. 14 9 22.1		— 1.8	"	B12
2634		+2.7	Sept. 6 7 57.1		+ 1.4	"	"
			1823				
3018		+3.3	Sept 12 9 14.3		— 15.3	Wm	H1
			1825				
3282		+6.0	Oct. 8 8 39.2		— 20.3	"	"
			1826				
3335		—3.2	Mar. 9 8 22.2		+ 13.8	Ol	D
			1831				
4074		+5.6	Dec. 27 7 19.3		— 8.7	Hd	H2
			1832				
4088		+1.0	Feb. 5 10 53.2		— 0.6	"	"
			1839				
5045		—0.8	Aug. 11 12 4.9:		+ 18.9	JH	R1
5068		+6.5	Oct. 16 10 7.2:		— 23.9	"	"
			1840				
5113	—11.3	—1.3	Feb. 22 10 54.3:		— 18.2	A	D
5114	— 5.2	—1.7	25 7 55.4		— 6.1	"	"
5122	+ 6.0	—4.5	Mar. 19 6 40.3:		+ 7.5	"	"
5180	—17.9	+2.0	Sept. 1 13 42.9		— 7.0	"	"
5189	—13.8	+4.9	27 9 9.5:		— 0.6	"	"
5196	+ 2.0	+6.6	Oct. 17 10 51.3:		— 1.2	"	"
5218	—20.9	+6.1	Dec. 19 12 50.9		+ 2.3	"	"
5219	—30.7	+6.0	22 9 35.2		— 2.3	"	"
5220	— 2.3	+5.7	25 5 57.9:		— 28.5	"	"
			1841				
5249	— 1.4	—4.4	Mar. 18 9 57.3		— 7.6	"	"
5301	— 6.0	—0.3	Aug. 14 12 41.7		+ 13.6	"	"
5317	+ 7.9	+5.1	Sept 29 9 43.0		+ 12.4	"	"
5324	0.0	+6.7	Oct. 19 11 1.7:		— 11.3	"	"
			1842				
5452	—10.4	+6.7	Oct. 21 11 42.3		+ 9.6	"	"
5467	+ 3.3	+7.1	Dec. 3 12 5.4		+ 19.2	"	"
5468	— 6.9	+7.0	6 8 40.1		+ 5.0	"	"
			1843				
5566	— 8.6	+3.4	Sept 13 8 31.8		+ 4.4	"	"
			1844				
5612	—20.1	+2.5	Jan. 23 6 7.4		+ 10.7	"	"
			1845				
5837	—16.1	+7.2	Oct. 29 9 23.6		+ 4.8	"	"
			1846				
5934			Aug. 3 12 12.2	1	— 14.6	Sm	A17
5942			26 11 14.0	2	+ 16.0	"	"
5950	— 9.5	+4.0	Sept 18 9 16.5		— 7.6	A	D

E	Reduction to Sd.	⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1847 d h m		m		
6086			Oct. 13 8 52.3	3	+ 33.2	Sm	A17
6093			Nov. 2 10 9.7	3	+ 8.3	"	"
"	—11.1	+7.3	2 9 43.2		— 13.2	A	D
6094	—25.6	+7.4	5 6 40.8		— 4.5	"	"
"			5 6 38.6	3	— 11.7	Sm	A17
6107			Dec. 12 13 55.3	1	+ 29.3	"	"
6108			15 7 10.4	4	[—184.5]	"	"
			1848				
6116			Jan. 7 8 39.5	4	— 6.5	"	"
"	+ 2.2	+4.5	7 8 45.7		+ 4.7	A	D
6117	— 0.9	+4.2	10 5 27.3		— 2.6	"	"
"			10 5 26.2	1	— 8.7	Sm	A17
6123			27 10 14.0	3	— 14.3	"	"
"	— 6.5	+2.0	27 10 19.5		— 3.8	A	D
6206			Sept 21 9 49.3	2	— 17.4	Sm	A17
			1849				
6319			Aug. 11 10 16.4	4	+ 4.5	"	"
6335			Sept 26 7 9.4	3	— 5.0	"	"
6349			Nov. 5 10 39.7	3	+ 0.8	"	"
6357			28 9 12.1	4	+ 2.0	"	"
			1850				
6373			Jan. 13 6 14.1	3	+ 1.7	"	"
6379			30 11 7.4	4	+ 1.6	"	"
"	— 5.0	+1.7	30 10 45.7		— 15.1	A	D
6486			Dec. 3 6 10.1	4	— 7.4	Sm	A17
			1851				
6501			Jan. 15 6 22.7	2	— 8.2	"	"
6515			Feb. 24 10 5.8	3	+ 10.5	"	"
"	+ 0.4	—1.6	24 10 14.8:		+ 24.4	A	D
6583			Sept 7 9 19.6	2	+ 4.5	Sm	A17
6598	+ 0.5	+6.7	Oct. 20 9 39.2:		+ 10.7	A	D
			1852				
6650		—4.2	Mar. 17 11 45.5		— 5.3	RM	E
6651	— 7.9	—4.6	20 8 40.3		+ 0.6	A	D
"			20 8 25.0	4	— 19.7	Sm	A17
6695	—14.8	—3.0	July 24 12 20.2		— 10.6	A	D
6711			Sept. 8 9 45.8	3	+ 7.7	Sm	A17
6741			Dec. 3 10 15.3	4	+ 10.5	"	"
6748			23 12 10.3	2	+ 23.3	"	"
			1853				
6764		+0.7	Feb. 7 8 59.4		+ 15.2	RM	E
6830		—0.1	Aug. 15 14 20.6		— 10.2	"	"
6847	+ 1.5	+5.5	Oct. 3 8 18.0		— 3.8	A	D
6854	+11.0	+7.0	23 10 3.5		— 0.6	"	"
"	+ 2.2	+7.0	23 10 22.2		+ 18.1	Sd	W
"			23 9 52.5	4	— 16.5	Sm	A17
"		+7.0	23 10 12.0		+ 7.9	Kr	A1
6855	+ 0.1	+7.1	26 6 58.2:		+ 5.3	A	D
"			26 6 41.7	4	— 16.2	Sm	A17
6861			Nov. 12 11 46.8	4	— 4.4	"	"
"	— 9.6	+7.5	12 11 38.0		— 8.2	A	D
6862			15 8 41.4	4	+ 1.3	Sm	A17
6868	— 5.6	+7.2	Dec. 2 13 24.8		— 3.6	A	D
6869			5 10 2.2	3	— 20.1	Sm	A17
6876		+5.8	25 11 34.1		— 25.4	Ml	J1
"	—11.8	+5.8	25 11 53.5		— 6.0	Od	O
6877	— 1.4	+5.6	28 8 54.0		+ 5.6	"	"

(*Continued in next number.*)

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OCCULTATIONS OF STARS BY THE MOON DURING THE LUNAR ECLIPSE OF 1888 JAN. 28, OBSERVED AT THE U.S. NAVAL OBSERVATORY.

[Communicated by the Superintendent.]

No. of Star.	Mag.	Phenomenon	Wash. M.T.	Obs'r	Remarks
			h m s		
264	8.6	Immersion	6 12 21.89	F	
271	9.5	"	6 19 44.99	F	very faint
276	10	"	6 28 19.20	F	very faint, somewhat uncertain
276	10	"	6 29 4.4	H	doubtful, sky hazy
236	9.5	Emersion	6 30 24.55	F	
247	9.2	"	6 46 45.08	F	
290	11	Immersion	6 46 56.11	H	faint
284	6.5	"	6 52 6.21	H	good
284	6.5	"	6 52 6.51	P	sharp and satisfactory
284	6.5	"	6 52 6.61	F	
264	8 6	Emersion	6 57 45.39	F	
264	8.6	"	6 57 45.67	P	faint, but emersion apparently sharp and satisfactory
271	9.5	"	7 8 7.53	H	doubtful
269	9.5	"	7 8 46.03	H	fair
276	10	"	7 9 22.03	H	fair

The observers were A. Hall, with the 26-inch equatorial, power 383; E. Frisby, with 9½-inch equatorial, power 132; and H. M. Paul, with the comet-seeker, power 40. The first observation by Prof. Hall was by eye and ear, power 200. Only the last part of the eclipse could be reached with the 26-inch equatorial. The numbers of the stars and their magnitudes are taken from Struve's list. The moon rose in a bank of haze, and the sky was not quite clear at the end of the eclipse.

1888 *February* 8.

COMET 1888 *a*.

A *Science Observer* dispatch, received from Kiel, Feb. 21, announces the discovery of a comet by Sawerthal on the 18th. Its position was observed at Capetown, as follows:

Feb. 18.6059 Greenw. M.T., $\alpha = 19^h\ 11^m\ 32^s.8$ $\delta = -56°\ 3'\ 44''$.

The daily motion was $+1°\ 44'$ in α, and $1°\ 15'$ northward.

It is described as of about the seventh magnitude, but visible to the naked eye, with well-defined nucleus, and a tail about 2° long. It ought to be visible in these latitudes very soon.

ADVERTISEMENT.

A volume of the *Astronomical Journal* consists of twenty-four numbers, with a table of contents and alphabetical index. The price of subscription is $5.00, payable in advance. This includes the postage to any address within the international postal union; but, for countries not in the union, the expense of postage is to be added.

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CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 167.

VOL. VII. BOSTON, 1888 MARCH 6. NO. 23.

ON THE PERIOD OF *ALGOL*.

BY S. C. CHANDLER, JR.

TABLE OF OBSERVED MINIMA — (*Continued*).

E	Reduction to Sd.	Reduction to ☉	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1854 d h m		m		
6885	— 3.6	+3.0	Jan. 20 7 5.4		— 14.[illegible]	A	D
6899		—2.2	Mar. 1 10 50.3		+ 6.[illegible]	Nl	A1
"		—2.2	1 12 12.6		?	Ml	J1
"	— 2.3	—2.2	1 10 39.5		— 4.4	Sd	W
6900	— 6.0	—2.6	4 7 20.4		— 12.4	A	D
"		—2.6	4 7 21.9		— 10.9	Nl	A1
6906		—4.6	21 12 25.2		— 0.9	Ml	J1
6907		—4.9	24 9 36.8		+ 11.9	RM	E
6958	0.0	+0.1	Aug. 17 15 7.5:	¼	+ 19.5	V	A3
6959	— 1.2	+0.5	20 11 27.8		— 9.1	Sd	W
"	— 4.2	+0.4	20 11 24.7:		— 12.2	A	D
6966		+3.0	Sept. 9 13 28.1		+ 9.0	Kr	A1
"		+3.0	9 13 26.1		+ 7.0	Bn	"
6967	— 2.8	+3.4	12 10 25.3		+ 17.3	Od	O
"	— 3.3	+3.4	12 10 7.6		— 0.4	Sd	W
"	— 7.0	+3.4	12 10 11.5		+ 3.6	A	D
"		+3.4	12 9 57 0		— 11.0	Bn	A1
6973		+5.2	29 14 59.1		— 2.2	"	"
6974		+5.4	Oct. 2 11 49.2		— 0.9	Kr	"
"	— 3.4	+5.4	2 12 4.5		+ 14.4	Sd	W
"	+ 6.6	+5.4	2 11 58.1		+ 8.0	A	D
"	— 5.9	+5.4	2 11 59.4		+ 9.3	Od	O
"		+5.4	2 12 3.6		+ 13.5	Nl	A1
"		+5.4	2 11 51.5		+ 1.4	Bn	"
"	— 8.5	+5.4	2 11 58.6:	¼	+ 8.5	V	A3
6981		+7.0	22 13 36.8		+ 4.5	Ml	J1
"	— 2.0	+7.0	22 13 24.0		— 8.3	Sd	W
6983	— 2.2	+7.2	28 7 7.0		— 3.1	A	D
"	+ 2.1	+7.2	28 7 10.4		+ 0.3	V	A3
"		+7.2	28 7 18.7		+ 8.6	Hs	A1
"		+7.2	28 7 14.9		+ 4.8	Kr	"
"		+7.2	28 7 26.0		+ 15.9	Nl	"
6989		+7.6	Nov. 14 11 59.4		— 4.0	Bn	"
6990	— 2.6	+7.6	17 9 1.9		+ 9.6	Od	O
6997		+7.0	Dec. 7 10 32.6		— 1.9	Kr	A1
"	— 4.2	+7.0	7 10 27.8		— 6.7	Sd	W
"	+ 1.3	+7.0	7 10 27.9		— 6.6	A	D
"	— 0.8	+7.0	7 10 53.1		+ 18.6	Od	O
6998	— 6.0	+6.9	10 7 33.5		+ 10.1	"	"
"	— 2.3	+6.9	10 7 29.7		+ 6.3	V	A3
7004	— 3.0	+5.7	27 12 12.2		— 4.5	Sd	W
			1855				
7012	— 4.4	+3.1	Jan. 19 10 41.0		— 6.7	Od	O
"	+ 0.5	+3.1	19 10 52.0		+ 4.3	A	D
"		+3.1	19 10 43.9		— 3.8	Hs	A2

E	Reduction to Sd.	Reduction to ☉	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1855 d h m		m		
7012		+3.1	Jan. 19 10 43.5		— 4.2	Hk	A2
"	— 1.4	+3.1	19 10 48.6		+ 0.9	V	A3
7013	+ 3.8	+2.8	22 7 49.4		+ 12.8	A	D
"			22 7 34.5	4	— 7.1	Sm	A17
7019		+0.6	Feb. 8 12 20.5		— 9.4	Wn	A2
7026	— 0.6	—2.0	28 14 13.7		+ 1.6	St	J1
7027	+ 2.8	—2.4	Mar. 3 11 1.5		+ 0.5	V	A3
7062		—7.0	June 11 19 26.6		— 5 2	Ml	J1
7092		+2.5	Sept. 5 19 44.7		— 13.6	"	"
7093		+2.8	8 16 41.1		— 6.0	"	"
7094		+3.2	11 13 31.6		— 4.4	"	"
"	— 1.5	+3.2	11 13 39.2		+ 3.2	Sd	W
7103			Oct. 7 9 3.8	4	+ 2.8	Sm	A17
7116		+7.6	Nov. 13 15 17.9		— 13.5	Ml	J1
7118	+ 6.6	+7.5	19 9 9.0		— 0.2	A	D
"			19 9 11.7	3	— 2.5	Sm	A17
7124		+7.1	Dec. 6 13 48.7		— 13.8	Ml	J1
			1856				
7133	— 5.0	+5.2	Jan. 1 9 23.0		+ 0.6	Od	O
7149		—0.4	Feb. 16 6 31.6		+ 7.1	Bn	A4
"		—0.4	16 6 27.5		+ 3.0	Wn	A2
7156	— 5.4	—2.9	Mar. 7 8 1.2		— 5.5	Od	O
"			7 8 18.5	3	+ 6.8	Sm	A17
7163		—5.3	27 9 51.2		+ 2.4	Bn	A4
"	— 3.0	—5.3	27 9 41.8		— 7.0	A	D
"		—5.3	27 9 32.6		— 16.2	Wn	A2
7207	— 1.9	—2.1	July 31 13 34.7		— 4.9	Sd	W
"		—2.1	31 13 47.7		+ 8.1	Hk	A3
7208		—1.7	Aug. 3 10 50.6		+ 22.2	"	"
7229	— 0.3	+5.4	Oct. 2 15 36.8		+ 1.9	F	J2
7230		+5.7	5 12 30.8		+ 7.0	Bn	A4
7237	— 4.6	+7.1	25 13 47.3		— 18.7	Od	A5
"		+7.1	25 13 58.5		— 7.5	Ml	J1
7238	— 4.6	+7.2	28 11 3.4		+ 8.5	Od	A5
"	+ 1.7	+7.2	28 10 55 3		+ 0.4	A	D
"		+7.2	28 11 8.2		+ 13.3	Hk	A3
7239	+ 2.9	+7.3	31 7 44.7		+ 1.0	Sd	W
"	— 6.3	+7.3	31 7 47.0		+ 3.3	A	D
"			31 7 52.5	3	+ 3.8	Sm	A17
"	— 4.6	+7.3	31 7 41.5		— 2.2	Od	A5
"		+7.3	31 7 54.9		+ 11.2	Hk	A3
"		+7.3	31 7 43.5		— 0.2	Bn	A4
"		+7.3	31 7 40.2		— 3.5	Wn	A2
7242	— 0.7	+7.5	Nov. 8 22 14.6		+ 4.2	F	J2
7243	— 0.8	+7.6	11 18 55.8		— 3.5	St	J1

* See p. 174. HERSCHEL OR BRÜHL?

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E	Reduction to Sd.	⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1856 d h m		m		
7251	— 1.7	+7.2	Dec. 4 17 28.0		— 2.3	St	J4
7252	— 2.5	+7.0	7 14 19.9		+ 0.7	Ms	J2
"	— 0.8	+7.0	7 14 20.1		+ 0.9	F•	"
7260	— 0.5	+5.4	30 12 49.4		— 0.8	"	"
			1857				
7261	+ 6.2	+5.1	Jan. 2 9 37.5		— 1.6	Sd	W
"		+5.1	2 9 42.1		+ 3.0	Kr	A2
"		+5.1	2 9 41.1		+ 2.0	Wn	A2
7268		+2.7	22 12 38.9		[+ 77.7]	RM	E
7269		+2.4	25 10 6.1		[+116.0]	"	"
7275	— 2.0	+0.1	Feb. 11 13 3.7		+ 0.3	Ms	J3
7276		—0.3	14 10 1.0		+ 8.7	Wn	A6
"	— 1.5	—0.3	14 9 53.4		+ 1.1	Sd	W
"			14 10 24.7	4	+ 27.4	Sm	A17
7277			17 6 24.5	4	— 21.6	"	"
"		—0.6	17 6 50.9		+ 9.8	Bn	A4
7283	— 0.5	—0.5	Mar. 6 11 34.8		+ 0.4	Ms	J3
7343	+ 0.4	+1.1	Aug. 25 12 24.5		— 2.8	Sd	W
"	— 3.0	+1.1	25 12 23.0		— 4.3	A	D
7349	— 0.6	+3.2	Sept 11 17 18.6		— 1.9	Ms	J5
7351		+3.9	17 11 1.8		+ 3.5	Hn	A18
"		+3.9	17 10 56.7		— 1.6	Wn	A6
"	— 6.2	+3.9	17 10 48.4		— 9.9	A	D
7357	— 2.2	+5.7	Oct. 4 15 45.6		— 6.0	Ms	J5
7358		+5.9	7 12 42.4		+ 1.9	Wn	A6
7360		+6.3	13 6 28.0		+ 9.8	"	"
7363		—0.6	21 20 45.0		+ 0.1	Ms	J5
7366			30 11 34.8	4	+ 18.3	Sm	A17
"		+7.3	30 11 12.2		+ 0.7	Km	A18
7367			Nov. 2 7 50.0	4	— 15.4	Sm	A17
7370		—0.8	10 22 27.8		+ 0.8	Ms	J5
7373			19 12 30.8	3	— 27.9	Sm	A17
"		+7.6	19 12 43.6		— 10.1	Hn	A18
"		+7.6	19 12 52.7		— 1.0	Wn	A6
"	— 2.5	+7.6	19 12 51.0		— 2.7	A	D
7374			22 9 33.4	4	— 14.2	Sm	A17
7375			25 6 36.3	1	— 0.1	"	"
7381			Dec. 12 11 29.4	3	— 0.3	"	"
7382			15 8 6.5	4	— 12.1	"	"
			1858				
7389			Jan. 4 9 56.5	2	— 4.3	"	"
"	0.0	+4.8	4 10 5.4		+ 9.6	A	D
7390			7 6 55.2	4	+ 5.5	Sm	A17
"	— 4.9	+4.5	7 6 59.0		+ 14.3	A	D
7395	— 2.0	+2.9	21 14 37.8		— 11.3	St	J6
7397			27 8 48.8	4	+ 17.0	Sm	A17
"		+2.1	27 8 19.5		— 7.3	Km	A18
"	— 2.1	+2.1	27 8 30.9		+ 4.1	A	D
7398			30 5 21.2	1	+ 0.5	Sm	A17
7404	+ 6.1	—0.5	Feb. 16 10 32.7:		+ 23.7	A	D
7405	— 2.8	—0.9	19 6 59.0		+ 1.1	"	"
"			19 7 16.0	3	+ 13.1	Sm	A17
7410	— 0.1	—2.7	Mar. 5 14 54.9		— 7.5	St	J6
7412	— 2.6	—3.5	11 8 44.0		+ 4.0	A	D
"		—3.5	11 8 39.9		— 0.1	Wn	A8
7418	— 1.3	—5.3	28 13 32.0		— 1.3	Ms	J7
7464		—1.2	Aug. 7 10 43.2		— 18.7	Km	A18
"		—1.2	7 11 5.0		+ 3.1	Wn	A8

E	Reduction to Sd.	⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1858 d h m		m		
7477	— 0.5	+3.5	Sept 13 17 29.7		— 7.6	Ms	J9
7480			22 8 29.3	3	+ 20.3	Sm	A17
7485	— 0.7	+5.8	Oct. 6 16 8.8		+ 0.4	Ms	J9
7486	— 1.6	+6.1	9 12 53.8		— 3.5	St	J8
"		+6.1	9 13 11.1		+ 13.8	Wn	A8
7487	— 1.7	+6.3	12 9 45.1		— 1.0	Sd	W
"	— 9.2	+6.3	12 9 55.4		+ 9.3	A	D
7488			15 6 29.2	1	— 10.8	Sm	A17
7492	— 1.0	+7.1	26 17 44.8		— 5.8	Ms	J9
7495	+ 2.4	+7.4	Nov. 4 8 27.9:		+ 10.7	A	D
7501	— 1.2	+7.5	21 13 8.6		— 1.9	Ms	J9
7508	— 1.0	+6.8	Dec. 11 14 42.4		— 10.3	"	"
7510			17 8 33.9	5	— 1.5	Sm	A17
7511		+6.2	20 5 15.4		— 3.9	Wn	A8
7514	— 1.0	+5.5	28 19 42.2		— 3.8	Ms	J9
			1859				
7517			Jan. 6 10 25.9	1	+ 8.3	Sm	A17
7523	— 1.0	+2.6	23 14 59.4		— 6.5	Ms	J9
7524	— 1.0	+2.3	26 11 42.2		— 12.6	"	"
7525			29 8 40.3	3	— 8.4	Sm	A17
7526			Feb. 1 5 30.0	1	— 7.6	"	"
7530	— 0.7	0.0	12 16 38.7		— 9.4	Ms	J9
7539	— 0.5	—3.3	Mar. 10 11 59.4		— 8.7	"	"
7541		—4.0	Mar. 16 5 37.2		— 8.6	Wn	A8
7546	— 0.7	—5.5	30 13 36.0		— 14.2	Ms	J9
7548		—6.0	Apr. 5 7 24.2		— 3.8	Wn	A8
7584	+ 3.6	—3.8	July 17 12 35.7		— 12.1	A	D
"		—3.8	17 12 38.7		— 9.1	Sd	M
7592			Aug. 9 11 32.3	3	+ 8.4	Sm	A17
"		—1.0	9 11 21.0		+ 2.1	Wn	A8
7597	— 1.0	+0.9	23 19 12.6		— 10.7	Ms	J10
7598	— 1.0	+1.2	26 15 56.3		— 15.9	"	"
7600			Sept. 1 9 34.4	1	— 20.6	Sm	A17
7604	— 1.0	+3.3	12 20 52.9		— 12.6	Ms	J10
7606	— 1.0	+4.0	18 14 19.9		— 23.4	"	"
7607			21 11 30.4	3	— 6.8	Sm	A17
7615			Oct. 14 10 23.5	3	+ 15.3	"	"
7616			17 6 49.8	4	— 7.3	"	"
7622		+7.4	Nov. 3 11 47.7		+ 2.3	Hs	A9
"			3 11 54.2	4	+ 3.8	Sm	A17
"	— 9.1	+7.4	3 11 44.0		— 1.4	A	D
"		+7.4	3 11 38.2		— 7.2	Hk	A10
7623		+7.5	6 8 12.3		— 22.0	Hs	A9
"			6 8 22.7		— 16.6	Sm	A17
"	— 9.4	+7.5	6 8 29.9		— 4.4	A	D
7624			9 5 11.9	1	— 16.3	Sm	A17
7630			26 10 9.0	3	— 12.5	"	"
7631			29 7 9.3	1	— 1.1	"	"
7636	— 1.0	+6.7	Dec. 13 14 49.4		— 20.4	Ms	J10
7637	— 1.0	+6.5	16 11 37.7		— 21.0	"	"
			1860				
7643	— 1.0	+5.1	Jan. 2 16 39.8		— 12.2	"	"
7644	— 1.0	+4.8	5 13 22.0		— 18.9	"	"
7647			14 4 48.1	1	+ 35.5	Sm	A17
7658	— 1.0	—0.2	Feb. 14 16 50.9		— 14.4	Ms	J11
7659	— 1.0	—0.6	17 13 40.5		— 12.7	"	"
7661			23 7 24.6	2	— 12.4	Sm	A17
"		—1.3	23 7 36.5		+ 4.5	Hs	A9

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E	Reduction to Sd.	Reduction to ⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1860 d h m		m		
7667	— 1.0	—3.5	Mar. 11 12 9.5		— 15.8	Ms	J11
7720			Aug. 10 11 51.7	1	+ 10.4	Sm	A17
7721			13 8 19.7	1	— 10.5	“	“
7727			30 13 22.9	1	— 0.7	“	“
7728			Sept. 2 10 26.2	4	+ 13.8	“	“
7729			5 7 23.6	2	+ 22.3	“	“
7732	— 1.0	+3.6	13 21 12.7		— 10.3	Ms	J12
7733	— 1.0	+3.9	16 18 13.1		+ 1.2	“	“
7735		+4.5	22 11 49.8		+ 0.1	Sd	M
7736			25 8 54.9	4	+ 11.4	Sm	A17
7737			28 6 2.4	1	+ 30.0	“	“
7740	— 1.0	+5.9	Oct. 6 19 48.8		— 5.3	Ms	J12
7742			12 13 41.7	4	+ 4.8	Sm	A17
7744			18 7 32.9	4	+ 18.2	“	“
7758			Nov. 27 10 52.4	3	+ 13.3	“	“
7759			30 7 23.9	3	— 4.1	“	“
7763	— 1.0	+6.8	Dec. 11 18 32.7		— 5.9	Ms	J12
7764	— 1.0	+6.6	14 15 14.4		— 13.0	“	“
7765	— 1.0	+6.4	17 12 11.6		+ 6.2	“	“
7766			20 9 13.2	3	+ 2.9	Sm	A17
7767			23 6 6.2	3	+ 7.0	“	A17
			1861				
7773		+4.3	Jan. 9 10 24.7		— 22.8	Km	A18
7780		+1.8	29 12 17.7		— 12.0	“	“
7781			Feb. 1 9 16.8	4	— 6.8	Sm	A17
7782			4 5 46.5	2	— 26.0	“	“
7833			June 30 11 53.8	1	+ 7.9	“	“
7848			Aug. 12 11 47.2	4	— 12.1	“	“
7856			Sept. 4 10 49.7	4	+ 19.2	“	“
7857			7 7 21.9	1	+ 2.5	“	“
7887		+7.2	Dec. 2 7 41.9		+ 0.7	Sd	M
7894		+6.0	22 9 16.5		— 6.9	“	“
7895		+5.8	25 6 5.6		— 6.7	“	“
			1862				
7909			Feb. 3 9 36.8	4	— 5.0	Sm	A17
7910			6 6 26.4	3	— 4.3	“	“
7924	— 5.0	—4.3	Mar. 18 9 43.0:		— 7.2	A	D
7925			21 6 39.4	2	— 4.7	Sm	A17
7961			July 2 12 7.9	4	+ 3.4	“	“
			1863				
8036	— 1.0	+1.4	Feb. 2 12 42.7:		— 24.1	Ms	K
8112			Sept. 8 11 19.3	4	+ 11.0	Sm	A17
8113			11 8 4.6	3	+ 7.4	“	“
8120			Oct. 1 9 38.8	3	— 0.6	“	“
8126			18 14 47.2	4	+ 14.3	“	“
8128			24 8 14.5	1	+ 3.8	“	“
			1864				
8225			July 28 11 18.9	4	+ 4.6	“	“
8233			Aug. 20 9 54.3	2	+ 8.8	“	“
8240			Sept. 9 11 18.4	4	— 9.5	“	“
8241			12 8 10.2	4	— 6.6	“	“
8255			Oct. 22 11 9.5	3	— 32.0	“	“
8256			25 8 30.0	3	— 0.4	“	“
8278		+5.6	Dec. 27 10 14.9		— 6.4	Sd	M
			1865				
8294		+0.2	Feb. 11 6 51.1		— 32.7	R	N
8308		—4.8	Mar. 23 10 57.3		+ 8.9	Sd	M
8309			26 7 10.2		— 32.0	Sm	A17
	m	m	1865 d h m		m		
8353			July 30 11 19.9	3	— 14.3	Sm	A1
“		—2.2	30 11 32.7		+ 3.5	Sd	M
8360		+0.4	Aug. 19 13 22.8		+ 11.2	“	“
8369		+3.6	Sept 14 8 27.3		— 4.4	“	“
“			14 8 9.7		— 27.0	Sm	A1
8376		+5.6	~~Oct.~~ 14 10 14.5		+ 0.4	Sd	M
8377		+5.9	— 7 7 3.3		+ 0.3	“	“
*8382			21 15 10.3		+ 2.8	Lm	L
8383			24 12 6.3	4	+ 4.9	Sm	A1
8384			27 9 7.1	2	+ 16.8	“	“
8392			Nov. 19 7 23.0	2	+ 1.4	“	“
“		+7.6	19 7 12.9		— 3.7	Sd	M
			1866				
8413		+3.3	Jan. 18 12 27.2		+ 3.6	“	“
8414		+2.9	21 9 22.5		+ 10.0	“	“
“			21 9 10.6		— 1.9	J	A11
“			21 9 24.6	4	+ 7.1	Sm	A1
8415		+2.5	24 6 10.2		+ 8.8	Sd	M
8422	—16.5	—0.1	Feb. 13 7 36.4		— 7.4	A	D
“			13 8 7.8		+ 24.0	J	A11
8437		—5.3	Mar. 28 7 57.7		+ 0.3	Sd	M
8481			Aug. 1 12 8.6	4	+ 14.4	Sm	A1
8489			24 10 25.8	2	+ 0.3	“	“
8496			Sept. 13 11 54.6	1	— 13.2	“	“
8497			16 9 2.2	2	+ 5.5	“	“
8504		+5.8	Oct. 6 10 24.7		— 9.4	Sd	M
“			6 10 35.4	3	— 3.7	Sm	A1
8505			9 7 33.7	1	+ 5.7	“	“
8513			Nov. 1 5 54.7	3	— 4.5	“	“
			1867				
8541		+3.0	Jan. 20 12 37.6		— 6.0	Sd	M
8543			26 6 20.5	2	— 5.9	Sm	A1
8550			Feb. 15 8 4.5	4	— 4.2	“	“
“		—0.3	15 8 0.5		— 3.2	Sd	M
8557			Mar. 7 9 53.1	1	+ 2.0	Sm	A1
8617			Aug. 26 10 33.0	4	— 12.4	“	“
8625			Sept 18 9 23.7	4	+ 7.1	“	“
8632			Oct. 8 10 36.7	1	— 22.2	“	“
8648		+7.5	Nov. 23 7 54.4		— 2.0	Sd	M
			1868				
8670			Jan. 25 10 0.2	2	+ 3.0	Sm	A1
8678		—0.5	Feb 17 8 34.0		+ 10.6	Sd	M
“		—0.5	17 8 33.9		+ 10.5	Wn	A1
8730			July 15 10 52.3	1	+ 1.0	Sm	A1
8745			Aug. 27 10 45.4	1	— 19.4	“	“
8753			Sept 19 9 29.8	3	— 6.2	“	“
8754			22 6 23.2	1	— 1.7	“	“
8762			Oct. 15 5 6.8	1	+ 10.7	“	“
8769			Nov. 4 6 42.8	4	+ 5.8	“	“
8783			Dec. 14 9 42.9	3	— 20.1	“	“
			1869				
8791			Jan. 6 8 24.5	4	— 9.7	“	“
8798			26 10 25.8	4	+ 9.3	“	“
8805			Feb. 15 12 1.2	1	+ 2.4	“	“
8806			18 8 57.5	4	+ 9.8	“	“
8821		—5.8	Apr. 2 9 2.5		+ 6.4	Sd	M
8858			July 17 11 10.0	2	— 0.2	Sm	A1
8865			Aug. 6 12 42.0	1	— 10.5	“	“

* Mean of 10 minima.

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E	Reduction to		Observed Min.	p	O—C	Obs.	Ref.
	Sd.	⊙	Helioc. Paris M.T.				
	m	m	1869 d h m		m		
8866			Aug. 9 9 31.9	1	— 9.5	Sm	A17
8872		+1.3	26 14 27.8		— 2.0	Sd	M
8873			29 11 32.4	1	+ 8.7	Sm	A17
"		+1.6	29 11 21.7		+ 3.0	Sd	M
8874		+2.0	Sept. 1 8 8.9		+ 1.3	"	"
8888		+6.2	Oct. 11 11 25.8		— 6.8	"	"
"		+6.2	11 11 6.4		— 25.7	Pn	R2
8905		+7.4	Nov. 29 5 36.7		+ 13.4	Sd	M
8910		+6.7	Dec. 13 13 35.2		+ 7.4	"	"
8912		+6.3	19 6 58.5		— 7.0	Pn	R2
			1870				
8926		+2.0	Jan. 28 10 30.9		+ 0.9	Sd	M
8927		+1.6	31 7 16.1		— 2.8	"	"
8949		—5.9	Apr. 4 9 0.5		— 14.0	"	"
9001		+1.9	Aug. 31 11 77.6		— 9.2	"	A13
9002			Sept. 3 8 41.7	1	+ 11.1	Sm	A17
9009	—14.2	+4.6	23 9 51.4		— 16.4	Ln	S
"			23 10 7.6		— 0.2	*Ln*	S
9010		+4.8	26 7 6.7		+ 10.0	Sd	A13
9016			Oct. 13 11 49.4		— 5.7	Sm	A17
9017			16 8 44.4	2	+ 0.4	"	"
9024		+7.5	Nov. 5 10 15.5		— 5.7	Sd	A13
9025		+7.5	8 7 7.0		— 3.1	"	"
"			8 7 33.8	1	+ 18.7	Sm	A17
9033		+7.3	Dec. 1 5 41.5		+ 0.3	Sd	A13
			1871				
9048			Jan. 13 6 1.6	2	+ 2.2	Sm	A17
9055			Feb. 2 7 30.8	4	— 10.9	"	"
9063			25 6 0.5	2	— 12.3	"	"
9070		—4.1	Mar. 17 7 44.8		— 5.1	Sd	A13
9114			July 21 12 4.8	3	+ 19.1	Sm	A17
9121		—0.9	Aug. 10 13 18.1		— 4.8	Sd	A14
"			10 13 25.2	4	— 2.7	Sm	A17
9130			Sept. 5 8 44.8	3	— 3.0	"	"
"		+2.4	5 8 48.6		+ 5.8	Sd	A14
9138			28 7 12.4	1	— 6.4	Sm	A17
9144		+6.5	Oct. 15 12 8.4		+ 1.3	Sd	A14
9152			Nov. 7 10 25.8	4	— 17.4	Sm	A17
9160			30 8 57.2	2	— 16.9	"	"
			1872				
9176			Jan. 15 6 21.1	4	+ 4.9	"	"
9197		—4.0	Mar. 15 11 15.0		— 2.6	Sd	A14
9205		—6.2	Apr. 7 9 52.5		+ 3.9	"	"
9242			July 22 12 1.4	3	— 0.6	Sm	A17
9249			Aug. 11 13 35.7	1	— 8.5	"	"
"		—0.6	11 13 52.2		+ 13.0	Sd	A14
9250		—0.3	14 10 31.5		+ 3.5	"	"
"			14 10 1.1	3	— 31.9	Sm	A17
9257			Sept. 3 12 19.2	3	+ 4.1	"	"
"		+2.3	3 12 8.4		— 1.7	Sd	A14
9258		+2.7	6 9 1.3		+ 2.3	"	"
9264		+4.6	23 13 47.6		— 4.6	"	A15
9265			26 10 39.3	4	— 6.8	Sm	A17
9266			29 7 31.0	4	— 3.9	"	"
9272		+6.6	Oct. 16 12 31.7		+ 8.5	Sd	A15
"	— 9.5	+6.6	16 12 12.1		— 11.1	Ln	S
"			16 12 31.6		+ 8.4	*Ln*	S
9273			19 9 5.9	4	— 11.1	Sm	A17

E	Reduction to		Observed Min.	p	O—C	Obs.	Ref.
	Sd.	⊙	Helioc. Paris M.T.				
	m	m	1872 d h m		m		
9274			Oct. 22 6 8.2	3	+ 2.3	Sm	A17
9281			Nov. 11 8 12.7	4	+ 24.7	"	"
9282			14 4 56.2	2	+ 19.3	"	"
9288			Dec. 1 9 2.7	1	— 27.4	"	"
9289			4 6 7.2	4	— 11.8	"	"
			1873				
9319		—2.1	Feb. 28 6 41.2		+ 1.1	Sd	A15
9370			July 24 12 22.4	2	+ 5.0	Sm	A17
9386			Sept. 8 9 47.1	4	+ 27.9	"	"
9392		+4.8	25 14 17.1		+ 9.7	Sd	A15
9394			Oct. 1 8 5.9	1	+ 15.7	Sm	A17
"	— 1.2	+5.3	1 7 47.1		+ 1.9	Ln	S
"			1 7 56.3		+ 11.1	*Ln*	S
9401			21 9 34.7	4	+ 2.5	Sm	A17
9402			24 6 14.9	2	— 6.2	"	"
9409			Nov. 13 7 48.6	4	— 14.5	"	"
"		+7.6	13 8 5.4		+ 7.3	Sd	A15
9416	—11.1	+7.2	Dec. 3 9 39.1		— 1.1	Ln	S
"			3 9 51.2		+ 11.0	*Ln*	S
9424			26 8 13.3		— 2.8	Sm	A17
9425			29 5 5.0	1	0.0	"	"
			1874				
9431			Jan. 15 9 51.9	1	— 6.3	"	"
"		+3.6	15 10 0.6		+ 7.4	Sd	A16
9438		+1.1	Feb. 4 11 40.9		+ 5.7	"	"
9439		+0.7	7 8 27.6		+ 3.5	"	"
9440			10 5 13.9	1	— 4.0	Sm	A17
9446		—1.9	27 10 8.6		+ 2.5	Sd	A16
9462			Apr. 14 7 17.3		+ 9.4	*Ln*	S
9506		+0.2	Aug. 18 11 9.9		+ 12.1	Sd	A16
9514		+3.1	Sept 10 9 36.9		+ 8.2	"	"
9522	— 5.6	+5.6	Oct. 3 8 2.0		+ 2.4	Ln	S
"			3 8 10.6		+ 11.0	*Ln*	S
9529		+7.0	23 9 51.1		+ 9.5	Sd	A16
			1875				
9575		—2.5	Mar. 4 7 8.3		— 0.8	"	"
9627			July 31 9 52.3	1	+ 17.6	Sm	A17
9634			Aug. 20 11 17.6	4	+ 0.9	"	"
9635			23 8 38.2	1	+ 32.7	"	"
9640	+ 4.2	+2.6	Sept. 6 15 58.1		— 6.7	Ch	A20
9641			9 13 13.4	2	+ 14.7	Sm	A17
9642			12 10 13.3	4	+ 25.8	"	"
9649		+5.4	Oct. 2 11 36.5		+ 12.0	Gl	V1
9650			5 8 21.2	3	+ 2.8	Sm	A17
9658			28 6 41.9	4	— 7.3	"	"
9666			Nov. 20 5 36.9	1	+ 16.9	"	"
"		+7.6	20 5 32.5		+ 17.5	Gl	V1
"		+7.6	20 5 32.8		+ 17.8	Ln	F
			1876				
9681		+5.1	Jan. 2 5 36.2	4	+ 3.4	Sm	A19
"		+5.1	2 5 32.0		+ 4.2	Wl	"
9687		+3.2	19 9 56.6	4	— 29.4	Sm	"
9696		—0.1	Feb. 14 5 54.3		+ 13.4	Gl	VI
9703		—2.8	Mar. 5 7 17.7	4	— 9.9	Sm	A19
9754		—2.3	July 29 12 47.1	4	— 12.1	"	A21
9762		+0.6	Aug. 21 11 37.0	4	+ 7.0	"	"
9769		+3.1	Sept 10 13 17.0	4	+ 5.1	"	"
9770		+3.5	13 9 53.6	4	— 7.2	"	"

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E	Reduction to Sd.	Reduction to ⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1876 d h m		m		
9770		+3.5	Sept 13 9 47.9		— 7.9	Wl	A21
"	.	+3.5	13 10 10.5		+ 14.7	Gl	V1
9777		+5.6	Oct. 3 11 50.1		+ 12.3	"	"
"		+5.6	3 11 54.0	4	+ 11.2	Sm	A21
9778		+5.8	6 8 44.7	4	+ 13.1	"	"
"		+5.8	6 8 43.7		+ 17.1	Wl	A21
9779		+6.1	9 5 36.8	2	+ 16.3	Sm	"
9785		+7.1	26 9 36.8	4	— 36.8	"	"
9801		+6.8	Dec. 11 6 37.2	2	— 38.0	"	"
"		+6.8	11 6 54.7		— 15.5	Wl	A21
			1877				
9809		+4.9	Jan. 3 5 53.3	2	+ 7.2	Sm	A22
9824		—0.4	Feb. 15 5 54.0	1	— 4.8	"	"
9889		+0.5	Aug. 20 14 11.9	2	— 42.3	"	"
9890		+0.9	23 11 44.3	2	+ 1.3	"	"
9897		+3.4	Sept 12 13 11.8	4	— 13.2	"	"
9898		+3.7	15 10 16.7	4	+ 2.9	"	"
9906		+6.0	Oct. 8 8 11.1	2	— 33.6	"	"
9928		+6.9	Dec. 10 9 49.6	4	— 49.8	"	"
9929		+6.7	13 7 18.9	4	— 9.3	"	"
			1878				
9937		+4.8	Jan. 5 5 55.5	3	— 3.5	"	A23
10019		+1.5	Aug. 28 8 54.1	4	+ 9.3	"	"
10027		+4.2	Sept 20 7 18.2	4	+ 2.6	"	"
10042		+7.4	Nov. 2 7 35.1	2	+ 6.7	"	"
10050		+7.5	25 5 59.0	4	— 0.1	"	"
			1879				
10071		+2.6	Jan. 24* 8 0.3	4		"	A24
10073		+1.8	30 4 59.7	3	+ 17.0	"	"
10080		—0.9	Feb. 19 6 55.5	2	+ 30.8	"	"
10087		—3.4	Mar. 11 8 26.0	4	+ 19.4	"	"
10104		—7.4	Apr 27† 12 18.0	2	?	"	A24
10147		+1.7	Aug. 30 8 58.1	2	+ 0.4	"	"
10163		+6.5	Oct. 15 6 7.9	4	+ 8.6	"	"
10185		+6.4	Dec. 17 7 55.0	3	+ 1.0	"	"
			1880				
10192		+4.7	Jan. 6 9 28.1	3	— 7.9	"	A25
10193		+4.3	9 6 27.4	4	+ 2.6	"	"
10200		+1.9	29 7 43.3	3	— 23.5	"	"
10274		+1.5	Aug. 28 12 27.7	4	+ 5.9	"	"
10275		+1.9	31 9 34.0	3	+ 23.4	"	"
10282		+4.2	Sept 20‡ 11 6.4	3	+ 13.8	"	"
10283		+4.6	23 7 49.0	4	+ 7.6	"	"
10288			Oct. 7 15 51.6		+ 10.9	HC	U
10289			10 12 47.2		+ 17.7	"	"
10290		+6.4	13 9 59.7	4	+ 36.3	Sm	A25
10297			Nov. 2 11 9.9		+ 9.6	HC	U

E	Reduction to Sd.	Reduction to ⊙	Observed Min. Helioc. Paris M.T.	p	O—C	Obs.	Ref.
	m	m	1880 d h m		m		
10298		+7.5	Nov. 5 8 1.9	4	+ 7.7	Sm	A25
10299		+7.5	8 5 24.9	2	+ 41.9	"	"
10303			19 16 4.7		+ 11.3	HC	U
10304			22 13 14.7		+ 32.4	"	"
10310			Dec. 9 19 54.2		+ 18.8	"	"
10314		+6.2	21 5 6.4	3	+ 10.6	Sm	A25
			1881				
10318			Jan. 1 16 21.6		+ 15.4	HC	U
10321		+4.2	10 6 59.3	3	+ 21.5	Sm	A26
10394		—1.2	Aug. 7 14 2.9	2	— 1.1	"	"
10395		—0.8	10 11 0.9	3	+ 8.1	"	"
10410		+4.5	Sept 22 11 8.4	4	+ 2.8	"	"
10418		+6.5	Oct. 15 9 0.9	4	— 35.5	"	"
10426		+7.5	Nov. 7 7 47.4	3	— 19.8	"	"
10433		+7.4	27 9 50.3	3	+ 1.1	"	"
			1882				
10449		+4.0	Jan. 12 6 37.7	3	— 13.1	"	A27
10457		+1.1	Feb. 4 5 23.7	2	0.0	"	"
10472		—4.3	Mar. 19 5 51.1	2	+ 14.6	"	"
10547		+6.8	Oct. 20 5 57.2	1	— 41.2	"	"
10561		+7.4	Nov. 29 10 12.2	3	+ 9.5	"	"
10562		+7.3	Dec. 2 6 48.8	4	— 2.4	"	"
			1883				
10577		+3.8	Jan. 14 7 3.0	3	— 1.0	"	A28
10585		+0.8	Feb. 6 5 30.0	2	— 4.8	"	"
10650		—0.7	Aug. 11 14 6.7	2	— 23.5	"	"
10651		—0.3	14 11 11.3	2	— 7.7	"	"
10659		+2.6	Sept 6 9 59.8	4	+ 9.9	"	"
10667		+5.2	29 8 20.6	3	— 0.1	"	"
10674		+6.7	Oct. 19 9 43.4	3	— 19.2	"	"
10675		+6.9	22 6 45.6	3	— 5.9	"	"
10682		+7.5	Nov. 11 8 25.9	3	— 7.5	"	"
10690		+7.2	Dec. 4 6 58.6	3	— 5.7	"	"
10691		+7.0	7 4 29.4	0	+ 36.3	"	"
			1884				
10816		+7.3	Nov. 29 13 34.3		— 0.3	Sr	
			1885				
10856			Mar. 24 6 17. :		+ 8.4	Hg	V2
10914			Sept. 6 13 15.0		— 16.9	"	"
10952		+5.9	Dec. 24 12 5.4		— 12.9	Sr	
			1886				
11072		+7.2	Dec. 3 14 7.8		+ 7.8	Ch	
			1887				
11192		+7.6	Nov. 12 15 38.4		— 3.3	"	
"		+7.6	12 15 34.9		— 6.8	Rd	
11200		+7.1	Dec. 5 13 58.5		— 13.9	Ch	
"		+7.1	5 14 10.7		— 1.7	Rd	
"		+7.1	5 14 9.1		— 3.3	Sr	

* Probably should read Jan. 27. † Probably should read Aug. 27. ‡ Sept. 10 in original.

On the following pages I give an ephemeris of all minima of *Algol* for the next ten years, constructed on a plan analogous to that adopted for *U Ophiuchi* and *R Canis Majoris*. The values of the period, computed from the expression on page 172, range, for a number of years to come, within a fraction of a second of $2^d\ 20^h\ 48^m\ 51^s.0$. But 324 days $= 2^d\ 20^h\ 48^m\ 50^s.97345 \times 113$ periods, a commensurability which forms a convenient basis for the arrangement of the ephemeris.

The Greenwich M.T. of minimum, according to the elements on page 172, exact to the hundredth of a minute, is found for any date in the table by adding to the time in the right-hand column the value of the correction at the foot of the column, interpolated from the two values there given, which correspond to the first and last epochs in the column above. The numbering of the epochs is indicated at the head of the column.

It may be added that I have reduced the ephemerides of all the remaining variables of the *Algol* type to the same convenient form, and shall publish them as soon as the new investigations of the periods of these stars, which I have now in hand, are completed.

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TEN YEARS' EPHEMERIS OF *ALGOL* MINIMA; HELIOCENTRIC GREENWICH M.T.

11210 to 11266	11323 to 11379	11436 to 11492	11549 to 11605	11662 to 11718	11775 to 11831	11888 to 11944	12001 to 12057	12114 to 12170	12227 to 12283	12340 to 12396	12453 to 12509	Green-wich M.T.
1888	1888–89	1889–90	1890–91	1891	1892	1893	1894	1895	1895–96	1896–97	1897–98	h m
Jan. 3	Nov. 22	Oct. 12	Sept. 1	July 22	June 10	Apr. 30	Mar. 20	Feb. 7	Dec. 28	Nov. 16	Oct. 6	6 11.49
6	25	15	4	25	13	May 3	23	10	31	19	9	3 0.34
8	27	17	6	27	15	5	25	12	Jan. 2	21	11	23 49.19
11	30	20	9	30	18	8	28	15	5	24	14	20 38.04
14	Dec. 3	23	12	Aug. 2	21	11	31	18	8	27	17	17 26.89
17	6	26	15	5	24	14	Apr. 3	21	11	30	20	14 15.74
20	9	29	18	8	27	17	6	24	14	Dec. 3	23	11 4.59
23	12	Nov. 1	21	11	30	20	9	27	17	6	26	7 53.44
26	15	4	24	14	July 3	23	12	Mar. 2	20	9	29	4 42.29
29	18	7	27	17	6	26	15	5	23	12	Nov. 1	1 31.14
31	20	9	29	19	8	28	17	7	25	14	3	22 19.99
Feb. 3	23	12	Oct. 2	22	11	31	20	10	28	17	6	19 8.84
6	26	15	5	25	14	June 3	23	13	31	20	9	15 57.68
9	29	18	8	28	17	6	26	16	Feb. 3	23	12	12 46.53
12	Jan. 1	21	11	31	20	9	29	19	6	26	15	9 35.38
15	4	24	14	Sept. 3	23	12	May 2	22	9	29	18	6 24.23
18	7	27	17	6	26	15	5	25	12	Jan. 1	21	3 13.08
21	10	30	20	9	29	18	8	28	15	4	24	0 1.93
23	12	Dec. 2	22	11	31	20	10	30	17	6	26	20 50.78
26	15	5	25	14	Aug. 3	23	13	Apr. 2	20	9	29	17 39.63
29	18	8	28	17	6	26	16	5	23	12	Dec. 2	14 28.48
Mar. 3	21	11	31	20	9	29	19	8	26	15	5	11 17.33
6	24	14	Nov. 3	23	12	July 2	22	11	29	18	8	8 6.18
9	27	17	6	26	15	5	25	14	Mar. 3	21	11	4 55.03
12	30	20	9	29	18	8	28	17	6	24	14	1 43.88
14	Feb. 1	22	11	Oct. 1	20	10	30	19	8	26	16	22 32.73
17	4	25	14	4	23	13	June 2	22	11	29	19	19 21.58
20	7	28	17	7	26	16	5	25	14	Feb. 1	22	16 10.43
23	10	31	20	10	29	19	8	28	17	4	25	12 59.28
26	13	Jan. 3	23	13	Sept. 1	22	11	May 1	20	7	28	9 48.13
29	16	6	26	16	4	25	14	4	23	10	31	6 36.98
Apr. 1	19	9	29	19	7	28	17	7	26	13	Jan. 3	3 25.83
4	22	12	Dec. 2	22	10	31	20	10	29	16	6	0 14.68
6	24	14	4	24	12	Aug. 2	22	12	31	18	8	21 3.53
9	27	17	7	27	15	5	25	15	Apr. 3	21	11	17 [illegible].37
12	Mar. 2	20	10	30	18	8	28	18	6	24	14	14 41.22
15	5	23	13	Nov. 2	21	11	July 1	21	9	27	17	11 30.07
18	8	26	16	5	24	14	4	24	12	Mar. 2	20	8 18.92
21	11	29	19	8	27	17	7	27	15	5	23	5 7.77
24	14	Feb. 1	22	11	30	20	10	30	18	8	26	1 56.62
26	16	3	24	13	Oct. 2	22	12	June 1	20	10	28	22 45.47
29	19	6	27	16	5	25	15	4	23	13	31	19 34.32
May 2	22	9	30	19	8	28	18	7	26	16	Feb. 3	16 23.17
5	25	12	Jan. 2	22	11	31	21	10	29	19	6	13 12.02
8	28	15	5	25	14	Sept. 3	24	13	May 2	22	9	10 0.87
11	31	18	8	28	17	6	27	16	5	25	12	6 49.72
14	Apr. 3	21	11	Dec. 1	20	9	30	19	8	28	15	3 38.57
17	6	24	14	4	23	12	Aug 2	22	11	31	18	0 27.42
19	8	26	16	6	25	14	4	24	13	Apr. 2	20	21 16.27
22	11	Mar. 1	19	9	28	17	7	27	16	5	23	18 5.12
25	14	4	22	12	31	20	10	30	19	8	26	14 53.97
28	17	7	25	15	Nov. 3	23	13	July 3	22	11	Mar. 1	11 42.82
31	20	10	28	18	6	26	16	6	25	14	4	8 31.67
June 3	23	13	31	21	9	29	19	9	28	17	7	5 20.52
6	26	16	Feb. 3	24	12	Oct. 2	22	12	31	20	10	2 9.37
8	28	18	5	26	14	4	24	14	June 2	22	12	22 58.22
11	May 1	21	8	29	17	7	27	17	5	25	15	19 47.06
m +0.07 to −0.12	m −0.38 to −0.59	m −0.81 to −1.08	m −1.20 to −1.38	m −1.38 to −1.33	m −1.16 to −0.84	m −0.43 to +0.22	m +1.04 to +2.02	m +3.27 to +4.78	m +6.44 to +8.31	m +10.50 to +12.88	m +15.50 to +18.37	

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Computed from the Elements 1888 Jan. $3^d\ 7^h\ 21^m\ 29^s.23$ (Greenw. M.T.) $+\ 2^d\ 20^h\ 48^m\ 55^s.425\ E'$ $+\ 173^m.3 \sin(\frac{1}{50}E'+202°\ 30')\ +18^m.0 \sin(\frac{3}{40}E'+203°\ 15')\ +3^m.5 \sin(\frac{1}{8}E'+90°\ 20')$; where $E' = E - 11210$

11267 to 11323	11380 to 11436	11493 to 11549	11606 to 11662	11719 to 11775	11832 to 11888	11945 to 12001	12058 to 12114	12171 to 12227	12284 to 12340	12397 to 12453	12510 to 12566	Greenwich M.T.
1888	1889	1890	1891	1892	1892–93	1893–94	1894–95	1895	1896	1897	1898	h m
June 14	May 4	Mar. 24	Feb. 11	Jan. 1	Nov. 20	Oct. 10	Aug. 30	July 20	June 8	Apr. 28	Mar. 18	16 35.91
17	7	27	14	4	23	13	Sept. 2	23	11	May 1	21	13 24.76
20	10	30	17	7	26	16	5	28	14	4	24	10 13.61
23	13	Apr. 2	20	10	29	19	8	29	17	7	27	7 2.46
26	16	5	23	13	Dec. 2	22	11	Aug. 1	20	[illegible]	30	3 51.31
29	19	8	26	16	5	25	14	4	23	13	Apr. 2	0 40.16
July 1	21	10	28	18	7	27	16	6	25	15	4	21 29.01
4	24	13	Mar. 3	21	10	30	19	9	28	18	7	18 17.86
7	27	16	6	24	13	Nov. 2	22	12	July 1	21	10	15 6.71
10	30	19	9	27	16	5	25	15	4	24	13	11 55.56
13	June 2	22	12	30	19	8	28	18	7	27	10	8 44.41
16	5	25	15	Feb. 2	22	11	Oct. 1	21	10	30	19	5 33.26
19	8	28	18	5	25	14	4	24	13	June 2	22	2 22.11
21	10	30	20	7	27	16	6	26	15	4	24	23 10.96
24	13	May 3	23	10	30	19	9	29	18	7	27	19 59.81
27	16	6	26	13	Jan. 2	22	12	Sept. 1	21	10	30	16 48.66
30	19	9	29	16	5	25	15	4	24	13	May 3	13 37.51
Aug. 2	22	12	Apr. 1	19	8	28	18	7	27	16	6	10 26.36
5	25	15	4	22	11	Dec. 1	21	10	30	19	9	7 15.21
8	28	18	7	25	14	4	24	13	Aug. 2	22	12	4 4.06
11	July 1	21	10	28	17	7	27	16	5	25	15	0 52.91
13	3	23	12	Mar. 1	19	9	29	18	7	27	17	21 41.75
16	6	26	15	4	22	12	Nov. 1	21	10	30	20	18 30.60
19	9	29	18	7	25	15	4	24	13	July 3	23	15 19.45
22	12	June 1	21	10	28	18	7	27	16	6	26	12 8.30
25	15	4	24	13	31	21	10	30	19	9	29	8 57.15
28	18	7	27	16	Feb. 3	24	13	Oct. 3	22	12	June 1	5 46.00
31	21	10	30	19	6	27	16	6	25	15	4	2 34.85
Sept. 2	23	12	May 2	21	8	29	18	8	27	17	6	23 23.70
5	26	15	5	24	11	Jan. 1	21	11	30	20	9	20 12.55
8	29	18	8	27	14	4	24	14	Sept. 2	23	12	17 1.40
11	Aug. 1	21	11	30	17	7	27	17	5	26	15	13 50.25
14	4	24	14	Apr. 2	20	10	30	20	8	29	18	10 39.10
17	7	27	17	5	23	13	Dec. 3	23	11	Aug. 1	21	7 27.95
20	10	30	20	8	26	16	6	26	14	4	24	4 16.80
23	13	July 3	23	11	Mar. 1	19	9	29	17	7	27	1 5.65
25	15	5	25	13	3	21	11	31	19	9	29	21 54.50
28	18	8	28	16	6	24	14	Nov. 3	22	12	July 2	18 43.35
Oct. 1	21	11	31	19	9	27	17	6	25	15	5	15 32.20
4	24	14	June 3	22	12	30	20	9	28	18	8	12 21 05
7	27	17	6	25	15	Feb. 2	23	12	Oct. 1	21	11	9 9.90
10	30	20	9	28	18	5	26	15	4	24	14	5 58.75
13	Sept. 2	23	12	May 1	21	8	29	18	7	27	17	2 47.60
15	4	25	14	3	23	10	31	20	9	29	19	23 36.45
18	7	28	17	6	26	13	Jan. 3	23	12	Sept. 1	22	20 25.29
21	10	31	20	9	29	16	6	26	15	4	25	17 14.14
24	13	Aug. 3	23	12	Apr. 1	19	9	29	18	7	28	14 2.99
27	16	6	26	15	4	22	12	Dec. 2	21	10	31	10 51 84
30	19	9	29	18	7	25	15	5	24	13	Aug. 3	7 40 69
Nov. 2	22	12	July 2	21	10	28	18	8	27	16	6	4 29.54
5	25	15	5	24	13	Mar. 3	21	11	30	19	9	1 18.39
7	27	17	7	26	15	5	23	13	Nov. 1	21	11	22 7.24
10	30	20	10	29	18	8	26	16	4	24	14	18 56.09
13	Oct. 3	23	13	June 1	21	11	29	19	7	27	17	15 44.94
16	6	26	16	4	24	14	Feb. 1	22	10	30	20	12 33.79
19	9	29	19	7	27	17	4	25	13	Oct. 3	23	9 22.64
22	12	Sept. 1	22	10	30	20	7	28	16	6	Aug. 26	6 11.49
m −0.12 to −0.33	m −0.59 to −0.81	m −1.08 to −1.20	m −1.33 to −1.38	m −1.33 to −1.16	m −0.88 to −0.43	m +0.23 to +1.04	m +2.04 to +3.27	m +4.76 to +6.44	m +8.35 to +10.50	m +12.93 to +15.50	m +18.42 to +21.43	

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EPHEMERIS OF THE OLBERS COMET.

By FRANK MULLER.

In No. 2818 of the *Astronomische Nachrichten*, Dr. KRUEGER has given an ephemeris of OLBERS's comet, extending to March 10. On February 21, when the brightness relative to that at discovery was 0.25, the comet was pretty bright, strongly condensed, and easy to observe with the 26-inch equatorial. As the comet is favorably situated for observing, and its brightness is decreasing but slowly, I have thought it worth while to continue this ephemeris for the use of those in this country who have powerful telescopes. At its appearance in 1815 the comet was observed during 172 days; at this appearance it will probably be visible much longer. The unit for L is the brightness on Aug. 27.

After making some small corrections to GINZEL's elements, Dr. KRUEGER based his ephemeris on them. The correction to this ephemeris, January 25, was $+6^s$ in right-ascension and $+0'.3$ in declination; and as this correction does not appear to be changing appreciably, and the agreement is sufficiently close for finding, I have not thought it worth while to vary the elements.

I have reduced these elements, given in No. 2806 of the *Astronomische Nachrichten*, to the mean equinox of 1888.0; they are as follows:

$$T = 1887 \text{ Oct. } 8.4938 \text{ Berlin M.T.}$$

$$\left.\begin{aligned} \pi &= 149^\circ\ 48'\ 57'' \\ \Omega &= 84\ \ 28\ \ 30 \\ i &= 44\ \ 32\ \ 53 \end{aligned}\right\} 1888.0$$

$$\rho = 68\ \ 35\ \ 36$$

$$\log q = 0.078899$$

CONSTANTS FOR THE EQUATOR:

$$x = [9.854826]\ r \sin (v + 237^\circ\ 36'\ 41'')$$

$$y = [9.972377]\ r \sin (v + 168\ \ 39\ \ 50\ )$$

$$z = [9.891630]\ r \sin (v + 95\ \ 54\ \ 20\ )$$

EPHEMERIS FOR BERLIN MEAN MIDNIGHT.

1888	α	δ	log r	log Δ	L
	h m s	° ′			
Mar. 2	18 6 33	— 7 50.1	0.3716	0.3917	0.24
3	7 19	7 55.0			
4	8 4	7 59.8			
5	8 48	[illegible]			
6	9 30	[illegible]	[illegible]93	0.3895	
7	10 11	[illegible]			
8	[illegible]	[illegible]			
9	[illegible]	[illegible]			
10	[illegible]	[illegible]	[illegible]	[illegible]	0.23
11	[illegible]	[illegible]			
12	[illegible]	[illegible]			
13	[illegible]	[illegible]			
Mar. 14	18 14 16	— 8 47.0	0.3943	0.3843	
15	14 45	8 51.8			
16	15 12	8 56.4			
17	15 39	9 1.1			
18	16 3	9 5.9	0.4016	0.3814	0.22
19	16 26	9 10.7			
20	16 48	9 15.5			
21	17 8	9 20.3			
22	17 26	9 25.1	0.4088	0.3783	
23	17 43	9 30.0			
24	17 59	9 34.9			
25	18 13	9 39.8			
26	18 25	9 44.8	0.4159	0.3750	0.21
27	18 36	9 49.8			
28	18 45	9 54.8			
29	18 52	9 59.9			
30	18 58	10 5.0	0.4227	0.3716	
31	19 2	10 10.1			
Apr. 1	19 5	10 15.3			
2	19 6	10 20.6			
3	19 5	10 25.9	0.4295	0.3682	0.21
4	19 2	10 31.2			
5	18 58	10 36.6			
6	18 53	10 42.1			
7	18 45	10 47.6	0.4362	0.3648	
8	18 36	10 53.2			
9	18 26	10 58.8			
10	18 13	11 4.6			
11	17 59	11 10.2	0.4427	0.3615	0.20
12	17 43	11 16.0			
13	17 25	11 21.9			
14	17 6	11 27.8			
15	16 45	11 33.8	0.4491	0.3584	
16	16 23	11 39.8			
17	16 58	11 45.9			
18	15 32	11 52.1			
19	15 5	11 58.4	0.4555	0.3555	0.20
20	14 36	12 4.7			
21	14 5	12 11.1			
22	13 32	12 17.5			
23	12 58	12 24.0	0.4617	0.3529	
24	12 22	12 30.6			
25	11 45	12 37.2			
26	11 6	12 43.9			
27	10 25	12 50.6	0.4678	0.3507	0.19
28	9 43	12 57.4			
29	8 59	13 4.3			
30	8 14	13 11.2			
May 1	7 27	13 18.2	0.4738	0.3490	
2	7 39	13 25.3			
3	7 50	13 32.4			
4	7 59	13 39.5			
5	18 4 6	—13 46.7	0.4797	0.3479	0.18

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THE

ASTRONOMICAL JOURNAL.

No. 168.

VOL. VII. BOSTON, 1888 MARCH 23. NO. 24.

ASTRONOMICAL JOURNAL, NO. 167.—SUPPLEMENT.

COMET 1888 a.

Elements of the new southern comet, computed by Mr. FINLAY, at the Cape of Good Hope, were telegraphed by Dr. KRUEGER, Feb. 29.

From these Mr. CHANDLER computed an approximate ephemeris, which has been circulated by the *Science Observer*.

ELEMENTS AND EPHEMERIS OF COMET 1888 a

$$T = 1888 \text{ March } 18.18 \text{ Greenw. M.T.}$$

$$\omega = 4^\circ\ 29'$$

$$\Omega = 244\ \ 6$$

$$i = 43\ \ 57$$

$$q = 0.6845$$

$$\text{C—O} \quad \begin{array}{ll} \Delta\lambda \cos\beta = & -0'.5 \\ \Delta\beta \quad = & -0\ .2 \end{array}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

	α	δ	log r	log Δ	L.
	h m s	° ′			
Feb. 29.5	20 12 55	—40 56	9.8893	9.9510	1.39
Mar. 4.5	20 29 59	—34 44	9.8694	9.9542	1.50
8.5	20 45 26	—28 24	9.8532	9.9613	1.57
12.5	20 59 24	—22 6	9.8417	9.9712	1.58
16.5	21 13 52	—15 52	9.8369	9.9862	1.52
20.5	21 27 29	— 9 56	9.8364	0.0031	1.40
24.5	21 40 56	— 4 23	9.8431	0.0219	1.24
28.5	21 54 14	+ 0 45	9.8555	0.0420	1.07
Apr. 1.5	22 7 24	+ 5 28	9.8724	0.0626	0.90
5.5	22 20 21	+ 9 43	9.8927	0.0834	0.75

The brightness Feb. 18 is taken as unity for L.

March 7.

[Pending the definite arrangement of the notation for the variable stars in *Cetus*, for which only the letters *R* and *S* are assigned in SCHÖNFELD's catalogue, I have, in the palpable need of a letter for this star, designated it as *U Ceti*, leaving the letter *T* to be used for the one of which the variability was discovered by CHANDLER in 1887, and subsequently confirmed by SAWYER. Two other stars in the constellation have been announced as variable; but their periods have not yet been determined, nor their variability confirmed by a second observer. These are U.A. 142, and the one announced by C. H. F. PETERS in *Astr. Nachr.* 99, 125. Mr. SAWYER has watched the former for some years without detecting signs of variation. — G.]

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$$\rho = \ \ 68\ \ \ 35\ \ \ 36$$
$$\log q = 0.078899$$

CONSTANTS FOR THE EQUATOR:

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$$y = [9.972377]\ r \sin (v + 168\ \ 39\ \ 50\ )$$
$$z = [9.891630]\ r \sin (v + \ \ 95\ \ 54\ \ 20\ )$$

EPHEMERIS FOR BERLIN MEAN MIDNIGHT.

1888	α	δ	log r	log Δ	L
	h m s	° '			
Mar. 2	18 6 33	— 7 50.1	0.3716	0.3917	0.24
3	7 19	7 55.0			
4	8 4	7 59.8			
5	8 48	8 4.5			
6	9 30	8 9.3	0.3793	0.3895	
7	10 11	8 14.0			
8	10 50	8 18.7			
9	11 28	8 23.4			
10	12 4	8 28.2	0.3869	0.3871	0.23
11	12 40	8 32.9			
12	13 13	8 37.6			
13	18 13 45	— 8 42.3			
Mar. 14	18 14 16	— 8 47.0	0.3943	0.3843	
15	14 45	8 51.8			
16	15 12	8 56.4			
17	15 39	9 1.1			
18	16 3	9 5.9	0.4016	0.3814	0.22
19	16 26	9 10.7			
20	16 48	9 15.5			
21	17 8	9 20.3			
22	17 26	9 25.1	0.4088	0.3783	
23	17 43	9 30.0			
24	17 59	9 34.9			
25	18 13	9 39.8			
26	18 25	9 44.8	0.4159	0.3750	0.21
27	18 36	9 49.8			
28	18 45	9 54.8			
29	18 52	9 59.9			
30	18 58	10 5.0	0.4227	0.3716	
31	19 2	10 10.1			
Apr. 1	19 5	10 15.3			
2	19 6	10 20.6			
3	19 5	10 25.9	0.4295	0.3682	0.21
4	19 2	10 31.2			
5	18 58	10 36.6			
6	18 53	10 42.1			
7	18 45	10 47.6	0.4362	0.3648	
8	18 36	10 53.2			
9	18 26	10 58.8			
10	18 13	11 4.6			
11	17 59	11 10.2	0.4427	0.3615	0.20
12	17 43	11 16.0			
13	17 25	11 21.9			
14	17 6	11 27.8			
15	16 45	11 33.8	0.4491	0.3584	
16	16 23	11 39.8			
17	16 58	11 45.9			
18	15 32	11 52.1			
19	15 5	11 58.4	0.4555	0.3555	0.20
20	14 36	12 4.7			
21	14 5	12 11.1			
22	13 32	12 17.5			
23	12 58	12 24.0	0.4617	0.3529	
24	12 22	12 30.6			
25	11 45	12 37.2			
26	11 6	12 43.9			
27	10 25	12 50.6	0.4678	0.3507	0.19
28	9 43	12 57.4			
29	8 59	13 4.3			
30	8 14	13 11.2			
May 1	7 27	13 18.2	0.4738	0.3490	
2	7 39	13 25.3			
3	7 50	13 32.4			
4	7 59	13 39.5			
5	18 4 6	—13 46.7	0.4797	0.3479	0.18

Leander McCormick Observatory, 1888 *February* 24.

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THE

ASTRONOMICAL JOURNAL.

No. 168.

VOL. VII. BOSTON, 1888 MARCH 23. NO. 24.

ASTRONOMICAL JOURNAL, NO. 167.—SUPPLEMENT.

COMET 1888 a.

Elements of the new southern comet, computed by Mr. FINLAY, at the Cape of Good Hope, were telegraphed by Dr. KRUEGER, Feb. 29.

From these Mr. CHANDLER computed an approximate ephemeris, which has been circulated by the *Science Observer*.

ELEMENTS AND EPHEMERIS OF COMET 1888 a

$$T = 1888 \text{ March } 18.18 \text{ Greenw. M.T.}$$

$$\omega = 4^\circ 29'$$

$$\Omega = 244 \quad 6$$

$$i = 43 \quad 57$$

$$q = 0.6845$$

$$\text{C—O} \quad \begin{array}{l} \Delta\lambda \cos\beta = -0'.5 \\ \Delta\beta \quad\quad = -0.2 \end{array}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

	α	δ	$\log r$	$\log \Delta$	L.
	h m s	° '			
Feb. 29.5	20 12 55	—40 56	9.8893	9.9510	1.39
Mar. 4.5	20 29 59	—34 44	9.8694	9.9542	1.50
8.5	20 45 26	—28 24	9.8532	9.9613	1.57
12.5	20 59 24	—22 6	9.8417	9.9712	1.58
16.5	21 13 52	—15 52	9.8369	9.9862	1.52
20.5	21 27 29	— 9 56	9.8364	0.0031	1.40
24.5	21 40 56	— 4 23	9.8431	0.0219	1.24
28.5	21 54 14	+ 0 45	9.8555	0.0420	1.07
Apr. 1.5	22 7 24	+ 5 28	9.8724	0.0626	0.90
5.5	22 20 21	+ 9 43	9.8927	0.0834	0.75

The brightness Feb. 18 is taken as unity for L.

March 7.

[Pending the definite arrangement of the notation for the variable stars in *Cetus*, for which only the letters R and S are assigned in SCHÖNFELD's catalogue, I have, in the palpable need of a letter for this star, designated it as *U Ceti*, leaving the letter T to be used for the one of which the variability was discovered by CHANDLER in 1887, and subsequently confirmed by SAWYER. Two other stars in the constellation have been announced as variable; but their periods have not yet been determined, nor their variability confirmed by a second observer. These are U.A. 142, and the one announced by C. H. F. PETERS in *Astr. Nachr.* 99, 125. Mr. SAWYER has watched the former for some years without detecting signs of variation. — G.]

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1888	α	δ	log r	log Δ	L
	h m s	° ′			
Mar. 14	18 14 16	— 8 47.0	0.3943	0.3843	
15	14 45	8 51.8			
16	15 12	8 56.4			
17	15 39	9 1.1			
18	16 3	9 5.9	0.4016	0.3814	0.22
19	16 26	9 10.7			
20	16 48	9 15.5			
21	17 8	9 20.3			

13	18 13 45	— 8 42.3					5	18 4 6	—

Leander McCormick Observatory, 1888 February 24.

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ON THE NEW VARIABLE IN *CETUS*, DISCOVERED IN 1885 (*U Ceti*). 873

$2^h\ 26^m\ 45^s.1 \quad -13°\ 47'.2$ (1855.0)

BY EDWIN F. SAWYER.

The discovery of the variability of this star was announced in the *Astr. Nachr.*, No. 2660. It was evidently near maximum when found, and only the decrease of light could be observed. Up to the present time nothing further has been published regarding the star, although it has since been observed.

The recent publication of Dr. SCHÖNFELD's southern DM., has, however, enabled me to identify the comparison-stars, and reduce the observations. The variable was looked for early in 1886, and first seen on February 22, 2 steps < SDM. 13°,492 and 5 + steps > SDM. 13°,483, or about $7^M.9$. The increase of light was rapid and uniform, and it reached max- ... ea ... March; although the exact time could not be determi... its proximity to the sun. The maxi- ... steps < SDM. 12°,481 and 1 step ... The star was next observed on ... ar, and found = SDM. 13°,462, or ... increase of light a maximum was ... 6; the maximum brightness being ... 7, 1 or 2 steps > SDM. 13°,495 ... 492, or $7^M.3$; this being slightly fainter than the previous maximum in March. When last observed, December 21, it was 3 or four steps < SDM. 13°,492 and 2 or 3 steps > SDM. 13°,462, or $7^M.8$. Although the variable has now been observed at three returns to maximum, only one fairly good determination of this phase has been obtained; hence the period remains as yet uncertain; but a careful inspection of all the observations indicates that the period will prove to be one of moderate length, or about 235 ± days, in which case another maximum will be due early in March. The star reaches $7^M.0$ at maximum, and is below 10^M at minimum. The comparison-stars used, and the preliminary light-scale adopted, are as follows:

	α h m s	δ ° ′		°	Mag.	Light
a =	2 26 56.6	−12 57.9 =	SDM.	12,481	7.0	28.5
b =	2 22 25.1	−13 33.8 =	"	13,457	6.8	24.6
c =	2 30 53.6	−13 45.8 =	"	13,495	7.3	18.0
d =	2 29 22.8	−13 32.0 =	"	13,492	7.5	15.0
e =	2 22 50.7	−13 54.0 =	"	13,462	8.0	9.0
f =	2 27 36.0	−13 23.2 =	"	13,483	8.8	7.5
g =	2 27 1.1	−13 35.2 =	"	13,481	8.5	5.0

... nuary 25.

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19	16 26	9 10.7			
20	16 48	9 15.5			
21	17 8	9 20.3			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

13	18 13 45	— 8 42.3			

5	18 4 6	—13 46.7	0.4797	0.3479	0.18

Leander McCormick Observatory, 1888 *February* 24.

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		α (h m s)	δ (° ′)			°	Mag.	Light
a	=	2 26 56.6	—12 57.9	=	SDM.	12,481	7.0	28.5
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f	=	2 27 36.0	—13 23.2	=	"	13,483	8.8	7.5
g	=	2 27 1.1	—13 35.2	=	"	13,481	8.5	5.0

Cambridgeport, 1888 *January* 25.

NOTE. — Another maximum of this star has just been passed. It was first seen this year on Jan. 28; being then 5 steps > SDM. 13°,483, and equal to SDM. 13°,462; or $8^{M}.1$. The increase of light was very rapid and uniform, and a maximum was reached on February 24; when its brightness was 3 or 4 steps > SDM. 13°,457, and equal to SDM. 12°,481; or $6^{M}.8$. Its light remained unchanged for 11 days, from Feb. 17 to 28. The star is now slowly decreasing, and is now 2 steps < SDM. 12°,481, and 1 step > SDM. 13°,457; or $7^{M}.0$. Owing to its close approach to the sun, the star can only be observed for a few days longer. Its period appears to be a little shorter than is intimated above, probably about 228 days. The star is not very red.

March 7.

[Pending the definite arrangement of the notation for the variable stars in *Cetus*, for which only the letters *R* and *S* are assigned in SCHÖNFELD's catalogue, I have, in the palpable need of a letter for this star, designated it as *U Ceti*, leaving the letter *T* to be used for the one of which the variability was discovered by CHANDLER in 1887, and subsequently confirmed by SAWYER. Two other stars in the constellation have been announced as variable; but their periods have not yet been determined, nor their variability confirmed by a second observer. These are U.A. 142, and the one announced by C. H. F. PETERS in *Astr. Nachr.* 99, 125. Mr. SAWYER has watched the former for some years without detecting signs of variation. — G.]

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OBSERVATIONS OF THE ZODIACAL COUNTERGLOW.

BY E. E. BARNARD.

The counterglow is a peculiar zodiacal phenomenon, seen only in that part of the sky immediately opposite to the place of the sun. Though it has been known for many years, observations of it seem to be very rare.

It was discovered originally by BRORSEN, and independently by BACKHOUSE. In 1883, never having heard of it, I also independently detected it. It would therefore seem to be not so difficult as the great lack of observations might indicate. The observations of Prof. ARTHUR SEARLE of Harvard College Observatory, who has seen the counterglow in connection with other zodiacal phenomena, are the only ones I have yet seen.

During the last four years, I have, on different occasions, observed the counterglow while comet-seeking, and have at various times located it, as accurately as its diffuse nature would permit, upon a chart or by reference to some known star. These observations, besides confirming its singular relation to the position of the sun, have revealed at least one peculiarity that I believe has never been previously detected, *i.e.*, the singular changes of form to be hereinafter described.

Speaking from my own observations, the counterglow, when first seen in the fall, is a roundish mass of hazy light about ten degrees in diameter; and though probably very slightly so, it is not perceptibly brighter in the middle. Observations on successive nights show that it has a decided motion eastward among the stars, and that it lies on, or very close to the earth's orbit; and its longitude differs by very nearly, if not exactly, 180° from that of the sun. After passing the vernal equinox in the latter part of September and first of October, a perceptible change takes place in its form, a faint zodiacal band becomes visible, extending from it some distance on each side, and the counterglow assumes an elliptical form; later it becomes more flattened and the band of light more distinct, until finally this band is seen at midnight connecting the evening and morning zodiacal lights, and the counterglow a mere swelling, scarcely denser and but little broader than the band. I suspect that if it were followed longer it would prove to be entirely absorbed in this band of light. Prof. SEARLE has kindly communicated to me some observations made by him during the autumn of 1886, which seem to confirm this change in form.

The counterglow is best seen by averted or oblique vision, and I find that by squinting the eyes its density is apparently increased.

In its most distinct form its location is easy, and its place can be pretty closely determined, although at times it has been so faint that its position could be obtained only with a coarse approximation. So distinct does it become at times that its presence has been detected with the telescope, when using a low power, its existence being indicated by a dulling of the sky, as if a thin veil of dust were intervening.

The following notes and positions were made at Nashville, Burritt's chart being used in some cases, and the places brought forward to the time of observation.

1883 *October* 8. [First record, though seen several days earlier.] Quite dense, especially with the eyes squinted, or when viewed obliquely; there seems to be some extension east and west.

1883 *October* 20. Dim.

1883 *October* 29. Rather dim, 15° in diameter; faint zodiacal band extends through its place to the horizon, the counterglow is merely a swelling out of this band, and is a little denser; the band is 4° or 5° broad and very faint, but certain.

1883 *November* 18. Hazy, oblong and indefinite; the *Pleiades* are involved. Zodiacal band connecting with the southwest horizon.

1883 *November* 23. Pretty distinct; hazy, the light of the planets and stars make it uncertain of location. Zodiacal band form southwest horizon to counterglow.

1884 *October* 12. Elongated, and hazy; a zodiacal band extending east of it to the *Hyades*, and passing south of the *Pleiades*.

1884 *November* 10. Elliptical east and west; on the line from *Alcyone* to *α Arietis*, seven-tenths of the distance from *α Arietis*. Its axis as 1 : 2.

1885 *February* 6. Elongated; directly on a line from *Praesepe* to *Jupiter*, one-third the distance from *Praesepe*.

1885 *March* 19. Large.

1885 *October* 3. Large, hazy, 15° in diameter.

1885 *October* 8. There is a zodiacal band extending from the zodiacal light in the east, to the west horizon; it is rather narrow, and its axis passes about $4\frac{1}{2}$° south of the *Pleiades*. It is about 5° broad near the *Pleiades*, and passes into a large counterglow situated among the stars of the ribbon of the western fish.

1885 *October* 15. Large, hazy; estimated to be 25° long by 10° or 15° broad; very noticeable as a longish strip of nebulous light.

1885 *November* 3. Large, west of the *Pleiades*; length 12°, breadth 5°; it is dull and hazy, but decidedly conspicuous; cannot be certain of any zodiacal band connecting with horizon.

1885 *November* 5. Pretty dense, long and narrow; west and south of the *Pleiades*.

1886 *September* 23. A very diffuse roundish counterglow; no definite boundary to it, though it is pretty dense, and about 10° in diameter; it is feebly connected with a faint zodiacal band which passes from it to a little south of the *Pleiades*.

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1886 *September* 28. Very hazy and diffuse; it is roundish or a little elliptical, east and west; there is, at least, an extension towards the *Pleiades*, but cannot be certain of any extension in the opposite direction; 10° or 15° in diameter.

1886 *October* 1. Roundish, hazy; no extension west, but probably some to the east. Examining more carefully, there is a very faint extension to the west, but a more decided strip extends east, which is easy 4° broad, and its axis passes 5° south of the *Pleiades*, and probably 6° south of *α Arietis*. The counterglow is 10° to 15° in diameter.

1886 *October* 2. Pretty dense. I think it is perceptibly east of its place last night. There is no central condensation, though it grows quite dense with averted vision.

1887 *March* 14. Hazy; very indefinite, so indefinite that cannot be certain of its location.

1887 *March* 16. Faint, diffused and hazy. Sky poor, and counterglow not well but certainly seen. Its center about 1½° north and west of *β Virginis*.

Positions of the Counterglow.

Greenwich M.T.	α	δ	$\odot-\lambda$	β
	h m	°	°	°
1883 Oct. 8.742	0 56	+ 6.6	180.1	+0.6
20.617	1 45	+10.7	179.2	—0.1
29.622	2 11	+15.5	180.6	+2.2
Nov. 18.575	3 37	+18.7	180.2	—0.6
23.700	3 56	+18.0	180.9	—2.3
1884 Oct. 12.721	1 9	+ 7.5	181.6	+0.1
Nov. 10.659	3 11	+23.4	177.5	+5.3
1885 Feb. 6.679	9 9	+17.5	184.2	—1.0
Mar. 19.742	12 6	+ 2.5	179.3	+2.8
Oct. 3.742	0 41	+ 4.0	180.1	—0.4
15.763	1 15	+11.5	181.2	+3.2
1886 Sept. 23.742	0 6	+ 2.6	178.7	+1.8
28.659	0 24	+ 3.0	179.3	+0.6
Oct. 1.721	0 28	+ 2.0	181.9	—0.9
1887 Mar. 14.683	11 26	+ 6.4	184.6	—2.5
16.745	11 43	+ 3.9	181.7	—2.0

In the table, the times for the notes, as well as for the positions, are given in the first column. The second and third give the observed right-ascension and declination, the fourth gives the longitude of the sun ($\odot$) minus the longitude of the counterglow (λ), and the last shows the latitude of its center.

I have carefully avoided any prejudice in the observations, not knowing at any time beforehand just where the counterglow should be.

Considering the figures in columns four and five as representing different observations of constant quantities, and taking their means, giving equal weight, we have

$$\odot-\lambda = 180°.6 \pm 0°.3 \;; \quad \beta = +0°.4 \pm 0°.3$$

which lead me to believe that with more accurate observations these quantities will become 180° and 0°, respectively, though I cannot reconcile the positions of 1884 Nov. 10, and 1885 Feb. 6, with this, as I think they were well determined.

As to the nature of the counterglow, I have seen so little upon the subject that I do not know if any one has attempted an explanation of it.

That it is a nebulous body, revolving about the earth at an unknown distance with a period coincident with that of the earth, is highly improbable, though such would explain the observations. I have thought that it might be due to some abnormal condition of refraction,—the refracted light of the sun illuminating the matter that forms the zodiacal bands, if such matter exists, at some distance beyond the earth; it is well known that the middle of the earth's shadow at the distance of the moon is thus illuminated. This would account for the constant position opposite the sun. There are objections to this theory; for, if the observations can be thoroughly relied on, the counterglow varies slightly from the ecliptic, and $\odot-\lambda$ is not a constant quantity. But although this difference is not sufficiently great to be decisive, I think it worthy of attention.

I hope, hereafter, to have an opportunity to observe the counterglow under more favorable conditions. It is very desirable that as many observations of its position be secured as possible to determine whether the values of $\odot-\lambda$ and β are constant. It is also important that the changes of form be more carefully observed.

San Francisco, Cal., 1888 *February* 8.

ON THE OBSERVATION OF THE VARIABLES OF THE *ALGOL*-TYPE,

By S. C. Chandler, Jr.

The accompanying list of the minima of these stars, conveniently observable in America and Europe before July 1, is furnished in the hope that it will incite to the more abundant observation of their phenomena. It is, in fact, a copy of a working-list that I have been accustomed to prepare for my own use, and will be continued from time to time, as needed, in subsequent numbers of the Journal. The times are purposely given only with such approximate accuracy as will suffice for the observer to prepare properly his scheme of work for the evening. An accurate knowledge of the predicted minimum is extremely undesirable, and is scrupulously avoided by the experienced observer.

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In connection with this initial list, it seems appropriate to supply schedules of the comparison-stars. For the three newer variables of this type, *U Ophiuchi*, *Y Cygni*, and *R Canis Majoris*, I have already had occasion to give such lists in this volume of the *Astronomical Journal*. Similar ones for the other six will be found below. SCHÖNFELD's scales are given for *Algol*, *δ Librae*, and *S Cancri*; WINNECKE's for *U Coronae Borealis*; and approximate scales provisionally reduced from a portion of my own observations, for *λ Tauri* and *U Cephei*. I have added in the last column, as possibly of some convenience, the equivalent adjusted magnitudes in the scale generally used among astronomers, namely, that of *the Uranometria Nova*, the *Durchmusterung*, the *Uranometria Argentina*, and the *Southern Durchmusterung*.

COMPARISON-STARS AND LIGHT-SCALES OF ALGOL-TYPE VARIABLES.

STAR.	Notation.	1855 α	1855 δ	L	Mag.
		Algol.			
		h m s	° ′		
γ Androm.	c	1 55 0	+41 38	23.4	2.1
ι Aurigae	i	4 47 32	32 56	17.3	2.6
β "	h	1 46 36	20 6	16.7	2 6
ε Persei	ε	3 48 8	39 35	12.8	2.9
γ "	γ	2 54 20	52 56	10.9	3.0
β Triang.	b	2 0 56	34 18	9.1	3.2
δ Persei	δ	3 32 36	47 20	7.8	3.3
α Triang.	a	1 44 48	28 52	3.5	3.6
ρ Persei	ρ	2 55 56	38 17	var.	var.
ν "	ν	3 35 24	42 8	0.9	3.8
Algol	β	2 58 45	+40 24	20.8 *M*	2.3
				5.6 *m*	3.5
		λ Tauri.			
ε Tauri	ε	4 20 8	+18 52	8	3.6
ξ "	ξ	3 19 19	9 14	8	3.6
γ "	γ	4 11 32	15 17	6	3.8
f "	f	3 22 52	12 28	2	4.4
d "	d	4 27 40	9 53	1	4.5
λ "	λ	3 52 39	+12 5	10 *M*	3.4
				4 *m*	4.2

STAR.	Notation.	1855 α	1855 δ	L	Mag.
		δ Librae.			
		h m s	° ′		
F 37 Librae	f	15 26 15	— 9 34	15.2	4.8
ε "	e	15 16 21	9 48	12.5	5.1
U.A. 90 "	d	15 26 37	8 41	8.5	5.5
U.A. 102 "	c	15 30 51	8 18	3.5	6.0
U.A. 42 "	b	14 54 26	7 0	0.0	6.4
δ Librae "	δ	14 53 14	— 7 56	13.0 *M*	5.0
				2.0 *m*	6.2
		S Cancri.			
DM. 19.2097	a	8 37 29	+19 34	21.4	8.0
" 2094	d	8 37 4	19 24	17.1	8.5
" 2092	g	8 36 28	19 56	12.2	9.0
" 2088	b	8 34 50	19 36	9.5	9.3
" 2089	e	8 35 31	19 19	5.8	9.6
" 2086	f	8 34 28	19 23	0.5	10.2
" 2090	S	8 35 39	+19 33	19.0 M	8.2
				4 *m*	9.8
		U Coronae.			
DM. 32.2578	f	15 17 30	+32 20	15.8	7.7
" 2575	e	15 16 35	32 31	13	8.0
" 2577	d	15 16 58	32 4	10.2	8.2
" 2573	c	15 14 28	32 34	4.7	8.7
" 2572	b	15 13 48	32 22	0.0	9.1
" 2569	U	15 12 17	+32 11	19.0 *M*	7.5
				2.3 *m*	8.9
		U Cephei.			
DM. 81.13	k	0 29 1	+81 42	29	6.6
" 80.34	p	1 4 23	80 47	19	7.9
" 81.18	e	0 38 28	81 10	18.5	7.9
" 81.30	f	0 52 29	81 11	18	8.0
" 81.27	g	0 50 56	81 19	12	8.6
" 81.34	m	0 59 25	81 0	12	8.6
" 81.29	h	0 51 35	81 28	11	8.7
" 80.21	a	0 39 5	80 49	8	8.9
" 81.22	d	0 42 4	81 7	4	9.3
" 80.22	b	0 40 28	80 53	3	9.4
" 80 25	U	0 49 39	+81 6	25 *M*	7.1
				5 *m*	9.2

For comparison-stars of
U Ophiuchi, see p. 137 of this volume.
Y Cygni, " 47 " "
R Canis Majoris, " 151 " "

APPROXIMATE EPHEMERIS OF ALGOL-TYPE VARIABLES, 1888, GREENWICH M.T.

	March d	h		March d	h		March d	h		April d	h		April d	h
U Coron. Bor.	20	0	Algol	26	10	*U* Ophiuchi	31	13	*U* Ophiuchi	5	14	*δ* Librae	12	20
δ Librae	20	13	*R* Canis Maj.	26	11				*δ* Librae	5	20	*Y* Cygni	13	18
U Ophiuchi	20	16	*U* Ophiuchi	26	13		April		*U* Cephei	6	16	*U* Ophiuchi	14	19
Y Cygni	20	18	*Y* Cygni	26	18	*U* Cephei	1	17	*Y* Cygni	7	18	Algol	15	11
U Ophiuchi	21	12	*δ* Librae	27	13	*Y* Cygni	1	18	*U* Coron. Bor.	9	18	*U* Ophiuchi	15	16
U Cephei	22	17	*R* Canis Maj.	27	14	*U* Coron. Bor.	2	20	*U* Ophiuchi	9	19	*U* Coron. Bor.	16	15
δ Librae	22	21	*U* Cephei	27	17	*R* Canis Maj.	3	9	*δ* Librae	10	12	*U* Cephei	16	16
U Coron. Bor.	23	11	*Y* Cygni	29	18	*δ* Librae	3	12	*U* Ophiuchi	10	15	*Y* Cygni	16	17
Algol	23	13	*δ* Librae	29	21	*S* Cancri	3	20	*Y* Cygni	10	18	*δ* Librae	17	11
Y Cygni	23	18	*U* Ophiuchi	29	21	*R* Canis Maj.	4	13	*U* Cephei	11	16	Algol	18	8
U Ophiuchi	24	20	*U* Coron. Bor.	30	9	*Y* Cygni	4	18	*R* Canis Maj	12	12	*R* Canis Maj.	19	7
U Ophiuchi	25	16	*U* Ophiuchi	30	17	*U* Ophiuchi	4	18	Algol	12	15	*Y* Cygni	19	17

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	April d	h
δ Librae	19	19
U Ophiuchi	19	20
U Ophiuchi	20	16
U Ophiuchi	21	12
R Canis Maj.	21	14
U Cephei	21	15
Y Cygni	22	17
S Cancri	22	19
U Coron. Bor.	23	13
δ Librae	24	11
U Ophiuchi	24	21
Y Cygni	25	17
U Ophiuchi	25	17
U Ophiuchi	26	13
U Cephei	26	15
δ Librae	26	19
R Canis Maj.	28	9
Y Cygni	28	17
R Canis Maj.	29	13
U Coron. Bor.	30	11
U Ophiuchi	30	18
	May	
δ Librae	1	10

	May d	h
U Ophiuchi	1	14
U Cephei	1	15
Y Cygni	1	17
δ Librae	3	18
U Coron. Bor.	3	22
Y Cygni	4	17
Algol	5	13
U Ophiuchi	5	19
U Cephei	6	14
U Ophiuchi	6	15
U Ophiuchi	7	11
U Coron. Bor.	7	8
Y Cygni	7	17
Algol	8	10
δ Librae	8	10
Y Cygni	10	17
δ Librae	10	18
U Ophiuchi	10	19
U Coron. Bor.	10	19
U Cephei	11	14
U Ophiuchi	11	16
S Cancri	11	18
U Ophiuchi	12	12
Y Cygni	13	16

	May d	h
δ Librae	15	10
U Ophiuchi	15	20
U Cephei	16	14
U Ophiuchi	16	16
Y Cygni	16	16
U Ophiuchi	17	13
δ Librae	17	17
U Coron. Bor.	17	17
Y Cygni	19	16
U Ophiuchi	20	21
U Cephei	21	13
U Ophiuchi	21	17
δ Librae	22	9
U Ophiuchi	22	13
Y Cygni	22	16
U Coron. Bor.	24	15
δ Librae	24	17
Algol	25	15
Y Cygni	25	16
U Cephei	26	13
U Ophiuchi	26	18
U Ophiuchi	27	14
U Ophiuchi	28	10
Y Cygni	28	16

	May d	h
δ Librae	29	9
S Cancri	30	17
U Cephei	31	12
U Coron. Bor.	31	12
Y Cygni	31	16
δ Librae	31	16
U Ophiuchi	31	19
	June	
U Ophiuchi	1	15
U Ophiuchi	2	11
Y Cygni	3	16
δ Librae	5	8
U Cephei	5	12
Y Cygni	6	16
U Ophiuchi	6	16
U Coron. Bor.	7	10
U Ophiuchi	7	12
δ Librae	7	16
Y Cygni	9	15
U Cephei	10	12
U Coron. Bor.	10	21
U Ophiuchi	11	16
U Ophiuchi	12	13

	June d	h
Y Cygni	12	15
U Coron. Bor.	14	8
δ Librae	14	16
U Cephei	15	11
Y Cygni	15	15
U Ophiuchi	16	17
U Ophiuchi	17	13
U Coron. Bor.	17	19
U Ophiuchi	18	9
Y Cygni	18	15
U Cephei	20	11
Y Cygni	21	15
δ Librae	21	15
U Ophiuchi	21	18
U Ophiuchi	22	14
U Ophiuchi	23	10
Y Cygni	24	15
U Coron. Bor.	24	16
U Cephei	25	11
U Ophiuchi	26	19
Y Cygni	27	15
U Ophiuchi	28	11
δ Librae	28	15
U Cephei	30	11
Y Cygni	30	15

OCCULTATIONS OBSERVED DURING THE MOON'S ECLIPSE, 1888 *Jan.* 28,

BY LEWIS BOSS, AT ALBANY, N.Y.

The occultations reported in this communication were observed by aid of the thirteen-inch refractor of the Dudley Observatory,— magnifying power 250 diameters. The "eye and ear" method was employed. For the predictions and observing list I am indebted to the courtesy of Director STRUVE of the Pulkowa Observatory. The times recorded at the telescope are of the Dent sidereal clock, whose error was carefully determined by transits of the stars, *Polaris*, *o Piscium*, *β Arietis*, *α Arietis*, *γ Tauri*, and *ε Tauri*. The resulting correction was: $-47^s.94 - 0^s.022\,(T - 2^h\,50^m)$. In the table which follows are given, in the column "Recorded Time," the uncorrected times as they were noted at the telescope; the other columns appear to require no explanation.

*	Phen.	Rec. Time. h m s	Gr. M.S. Time h m s	Remarks.
c	Dis.	2 39 4.5	11 2 40.4	Instantaneous
a	Reap.	2 43 10.5	11 6 45.8	Good.
b	Reap.	2 56 20.8	11 19 53.9	Fairly good
e	Dis.	3 2 10.0	11 25 42.2	Uncertain.
d	Dis.	3 4 56.8	11 28 28.5	Projected on disc.
c	Reap.	3 36 53.0	12 0 19.5	Good.
d	Reap.	3 43 34.0	12 6 59.4	Near edge of field.

A tolerably thick haze increased the natural difficulty of observing at the low altitude which the moon had during totality. Assistant EGBERT, using the four-inch comet-seeker, was unable to see even the brighter stars within 20° of the moon's edge; and at times this was the case with the larger telescope.

The following table, containing places of stars referred to above, is copied from the Pulkowa list prepared for this eclipse.

Ref.	DM. No.	Mag.	App. α ° ′	App. δ ° ′
a	17 1961	8.7	131 23.15	+17 37.63
b	17 1962	9.5	131 26.11	17 30.07
c	17 1967	9.2	131 48.32	17 24.55
d	17 1968	8.6	131 58.88	17 35.91
e	17 1969	9.5	132 1.30	17 20.11

ANNOUNCEMENT WITH REFERENCE TO THE ASTRONOMICAL CODE.

I beg to announce that the new edition of the *Science Observer* Code is in the binder's hands, and will very shortly be ready for distribution. It forms a volume of about two hundred and fifty pages, and is divided into three parts, the number-code, its accompanying list of forty thousand words, and the phrase-code. The number-code and the phrase-code

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are substantially the same as in the previous edition, with the incorporation, however, with such improvements as were found to be practicable among the various suggestions which have been received from Dr. Krueger, Professor Adams, Dr. Copeland, Dr. Gould, and others who have had actual experience with them.

It is thought that this new edition will do away with the inconveniences which unavoidably attended the use of the previous one, and which were due to the defective character of the dictionary provisionally employed. The words are all numbered, obviating the necessity of counting, and all known sources of ambiguity have been removed. The number-words have been carefully chosen from the dictionaries of several languages; it being evident, after careful consideration of the subject, that this would be necessary to secure the requisite number of suitable words. They have been so selected that the literal arrangement of any word differs from that of every other by at least two letters, and all words of more than ten letters have been excluded.

It seems proper, in this place, to give briefly the history of the inception, introduction, and growth of the system, as it is at present organized, for the distribution of astronomical intelligence in this country; no connected account of the matter having been published heretofore.

In 1879, the writer, feeling that it would be a useful service to astronomy to provide for the publication and distribution of orbits of comets as soon as possible after discovery, began the issue of the special circulars of the *Science Observer*. In the course of the work attending the collection of the material for these circulars, the desirability of improvement in the existing system for telegraphing astronomical data naturally suggested itself. This subject was therefore frequently discussed before the Boston Scientific Society, and the immediate result was the preparation, in 1881, of a manuscript code by Mr. Chandler and myself, which was identical with the number-code, since printed.

To give this code a trial without interfering with the then existing system of international communication of discoveries, arrangements were made with Lord Crawford for the receipt or transmission of orbit messages. After a number of ocean tests between Dun Echt and Boston, the *Science Observer* Code was published under the title, "*On the telegraphic transmission of astronomical data; by S. C. Chandler, Jr., and John Ritchie, Jr.*," in the *Science Observer*, Vol. III., Nos. 9–10, Aug. 1, 1881. Later in the year, the general needs of astronomy having been considered, a "Phrase-Code" was put into manuscript, which, after two years' practical trial, was revised and printed for general distribution.

In 1882, upon the formation of a European association of astronomers, for announcements and for collection of news of astronomical discoveries, Dr. Krueger expressed a wish that the originators of the code would act as the center for the United States; and shortly afterwards, Professor Baird, Superintendent of the Smithsonian Institution, tendered to Mr. Chandler and myself the department of international exchange of astronomical information. We felt, however, that in undertaking the work, it could be most conveniently carried on by securing the cooperation of some established Observatory. The reasons are obvious; and among them, the aid which the instrumental equipment would afford. The nearness of Harvard College Observatory, together with the fact that Mr. Chandler had meanwhile become, and then was, associated with it, made it the institution most naturally to be looked to, for collaboration. Professor Pickering, who had become interested in the project, kindly tendered the cooperation of the Observatory; and, in default of any formal association of American Observatories, like that then just formed in Europe, offered to defray the expense of cable-messages relating to announcements of American discoveries. This offer of its influence and financial assistance was cheerfully accepted, and is gratefully acknowledged.

To facilitate some necessary business arrangements, especially with the telegraph companies, which would more readily treat with the representative of an institution than with an individual, Professor Pickering suggested the addition of my name to the staff of the Observatory. The appointment being nominal and without compensation, I saw no objection to accepting.

Meanwhile, as an undertaking intimately related to the foregoing, although independent of connection with any Observatory in particular, it has been my constant endeavor to make more efficient the service which the circulars were intended to render. To this end arrangements have been made from time to time with various Observatories, for the telegraphic interchange of positions of comets, for providing material for those who were willing to undertake orbit-computations, and, in the case of a widely prevailing storm, for securing positions from Observatories out of its range. The hearty encouragement and assistance met with in every direction in these endeavors, calls for my sincere thanks.

It is not expected that the sale of the Code will defray the cost of its publication; but in order to distribute the outlay in some degree, the price of each copy has been fixed at five dollars. To avoid needless delay in distributing the book, subscriptions may be sent me at once, by American astronomers, and arrangements have been made through Dr. Krueger for its distribution in Europe.

John Ritchie, Jr.

Boston, 1888 *March* 20. *P. O. Box* 2725.

COMET 1888 *a*.

Elements of the new southern comet, computed by Mr. Finlay, at the Cape of Good Hope, were telegraphed by Dr. Krueger, Feb. 29.

From these Mr. Chandler computed an approximate ephemeris, which has been circulated by the *Science Observer*.

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Elements and Ephemeris of Comet 1888 a

$T =$ 1888 March 18.18 Greenw. M.T.
$\omega =$ 4° 29′
$\Omega =$ 244 6
$i =$ 43 57
$q =$ 0.6845

C—O $\Delta\lambda \cos\beta =$ —0′.5
$\Delta\beta$ = —0 .2

Ephemeris for Greenwich Midnight.

	α (h m s)	δ (° ′)	log r	log Δ	L.
Feb. 29.5	20 12 55	—40 56	9.8893	9.9510	1.39
Mar. 4.5	20 29 59	—34 44	9.8694	9.9542	1.50
Mar. 8.5	20 45 26	—28 24	9.8532	9.9613	1.57
12.5	20 59 24	—22 6	9.8417	9.9712	1.58
16.5	21 13 52	—15 52	9.8369	9.9862	1.52
20.5	21 27 29	— 9 56	9.8364	0.0031	1.40
24.5	21 40 56	— 4 23	9.8431	0.0219	1.24
28.5	21 54 14	+ 0 45	9.8555	0.0420	1.07
Apr. 1.5	22 7 24	+ 5 28	9.8724	0.0626	0.90
5.5	22 20 21	+ 9 43	9.8927	0.0834	0.75

The brightness Feb. 18 is taken as unity for L.

[The foregoing elements and ephemeris were sent with No. 167, as a supplement.]

The comet was detected at the McCormick Observatory, on the morning of March 13, by Mr. Muller, whose observations are given in this number.

It has also been observed by Prof. Boss at Albany, and Prof. Frisby at Washington, as follows:

Local M.T. (d h m s)	App. α (h m s)	App. δ (° ′ ″)	Obs'r.
March 17 17 25 56	21 16 37.2	—14 46 54	Boss
18 17 10 34	21 19 52.7	—13 21 52	Frisby

OBSERVATIONS OF COMET 1888 a,

MADE AT THE LEANDER MCCORMICK OBSERVATORY,

BY FRANK MULLER.

1887 Local M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″	s	″
March 12 17 33 35	1	1	+2 11.23	–	20 59 5.87	–	n9.635	
13 17 33 31	2	4	–	+2 28.9	–	—20 36 15.9		0.803
13 17 40 36	2	5	+0 33.14	–	21 3 22.70	–	n9.628	
16 17 27 5	3	1	+4 25.14	–	21 13 21.73	–	n9.618	
16 17 33 7	3	1	–	+0 30.7	–	—16 11 24.2		0.793

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 56 57.68	—3.04	—21 58 41.1		Cincinn. Zones 3538.
2	21 2 52.52	—2.96	—20 38 43.8	—1.0	¼(Cin. Z. 3559+Cape 1850+B.VI.+Cambr. 1849
3	21 8 59.13	—2.54	—16 11 52.9	—2.0	Oeltz. Argelander 21244.

The observations were made with the filar micrometer of the 26-inch equatorial. On March 16, the comet had a nucleus of the 5th to the 6th magnitude, and the tail as seen in the dawn was fan-shaped, extending 3′ at a position-angle of 270°. On March 12 and 13, only the nucleus was seen. On March 12, Δδ was estimated as 4′.

University of Virginia, 1888 *March* 17.

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OBSERVATIONS OF OCCULTATIONS DURING THE TOTAL ECLIPSE OF THE MOON, 1888 *January* 28.

BY PROF. DAVID P. TODD.

Star. Struve's No.	Mag.	Phase.	Chronometer Birch 1217 M.T.	Error on G.M.T.	Greenwich Mean Time	Wt.
			h m s	s	h m s	
247	9.2	Disap.	11 2 22.0	+0.7	11 2 22.7	3
201	8.7	Reap.	11 7 17.9	+0.7	11 7 18.6	4
210	9.5	Reap.	11 20 5.5	+0.7	11 20 6.2	2
264	8.6	Disap.	11 27 19.5	+0.8	11 27 20.3	3
236	9.5	Reap.	11 44 24.0	+0.8	11 44 24.8	4
247	9.2	Reap.	12 0 23.8	+0.8	12 0 24.6	4
264	8.6	Reap.	12 8 3.8	+0.8	12 8 4.6	4

These occultations were observed with the Clark refractor, of $7\frac{1}{4}$ inches aperture, and a power of 100. The right-ascensions of the *Berliner Jahrbuch* were used in determining the time. The weights are assigned on a scale of excellence increasing from 1 to 5. The definitive position of the Observatory, from a late determination by the U.S. Coast and Geodetic Survey, is

Latitude $+42° 22' 17''.1$
Longitude $4^h 50^m 4^s.67$ west of Greenwich.

Elevation of the equatorial above sea-level, 410 feet.

Soon after twilight had disappeared, the eclipse itself was for several minutes occulted, by the tower of an adjacent building; so that many of the first phenomena, otherwise easily observable, were unhappily lost.

Amherst College Observatory, 1888 *March* 10.

COMETS OF THE YEAR 1887.

The dates are in Greenwich Mean Time, and the elements only approximate.

Designation	Perihelion	☊	ω	i	q	φ	Discoverer	Date	Synonym	
		° ′	° ′	° ′		° ′				
I	Jan. 11.23	337 43	63 36	137 0	0.005		Thome	Jan. 18	1887 *a*	Gt. Southern
II	Mar. 16.71	279 43	158 54	104 23	1.636		Brooks	Jan. 23	1887 *b*	
III	Mar. 28.40	135 27	36 29	139 49	1.007		Barnard	Feb. 16	1887 *d*	
IV	June 16.66	245 13	15 8	17 33	1.394	84 37	Barnard	May 12	1887 *e*	
V	Oct. 8.46	84 29	65 19	44 34	1.199	68 34	Brooks	Aug. 24	1887 *f*	Olbers's

The comet 1887 *c*, discovered by BARNARD January 23, is 1886 VIII.

TWO HUNDRED SEVENTY-THIRD ASTEROID.

An asteroid was discovered, March 8, by PALISA, at Vienna.

March 8.548 Greenw. M.T. $\alpha = 10^h 30^m 48^s$ $\delta = +10° 36'$ Daily motion -48^s in α, and 12′ northward.

CORRIGENDA.

No 166, p. 173. Index to Observers, GOODRICKE'S No. Minima, for 6 put 16.
173. " " " Total number, for 684 put 694.
No. 167, p. 179. Col. 2, E 8376, for Oct. 14 put Oct. 4.
184. Col. 2, α, April 17, for 16^m put 15^m.

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ASTRONOMICAL JOURNAL, NO. 168—SUPPLEMENT.

ELEMENTS AND EPHEMERIS OF COMET 1888 *a*,

BY LEWIS BOSS.

The elements here given were computed from the discovery-observation at the Cape, combined with an observation of March 13, made at the University of Virginia, and one by me on March 17. The observations were corrected for parallax, and the times for aberration by an ephemeris computed from FINLAY'S elements.

$$T = 1888 \text{ March } 16.9256 \text{ (Greenwich)}.$$

$$\left.\begin{aligned} \omega &= 359^\circ\ 44'\ 39'' \\ \Omega &= 245\ \ 29\ \ 13 \\ i &= 42\ \ 14\ \ 36 \end{aligned}\right\} \text{Apparent Equinox.}$$

$$\log q = 9.84461$$

The middle observation gives the following residuals (C—O):

$$\Delta\lambda \cos\beta = +38''; \ \Delta\beta = +10''$$

Comparison of an observation made at Washington by Prof. FRISBY, March 18, differs from the ephemeris place (C—O):

$$\Delta\alpha = -0^s.6; \ \Delta\delta = -2''$$

I carefully estimated the brightness of the comet on March 17 to be of the fifth magnitude. Theoretically the comet will be exactly three magnitudes fainter on May 24 than it was on March 17, or of the eighth magnitude.

Albany, N. Y., 1888 *March* 21.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1888		App. α	App. δ	log. Δ	L
		h m s	° '		
March	25.5	21 40 56	— 4 33.7	0.0292	1.06
March	29.5	21 53 27	+ 0 17.4	0.0487	.91
April	2.5	22 5 45	4 44.5	0.0684	.77
	6.5	22 17 49	8 48.5	0.0879	.63
	10.5	22 29 33	12 30.2	0.1071	.53
	14.5	22 40 57	15 51.7	0.1255	.43
	18.5	22 51 59	18 54.9	0.1432	.36
	22.5	23 2 37	21 41.9	0.1600	.30
	26.5	23 12 51	24 14.4	0.1759	.25
April	30.5	23 22 42	26 34.0	0.1908	.21
May	4.5	23 32 7	28 42.5	0.2048	.18
	8.5	23 41 8	30 41.2	0.2179	.15
	12.5	23 49 44	32 31.2	0.2301	.13
	16.5	23 57 54	34 13.5	0.2415	.11
	20.5	0 5 39	35 49.1	0.2520	.10
May	24.5	0 13 0	37 18.6	0.2618	.09

Light at discovery is the unit of brightness.

C.

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CORRIGENDA.

No 166, p. 173.	Index to Observers, GOODRICKE'S No. Minima, for 6 put 16.	
173.	" " " Total number, for 684 put 694.	
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THE

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THE

ASTRONOMICAL JOURNAL.

No. 169.

VOL. VIII. BOSTON, 1888 APRIL 6. NO. 1.

THE CONSTANT OF ABERRATION,

BY PROF. A. HALL.

[Communicated by Capt. R. L. PHYTHIAN, Superintendent Naval Observatory.]

§ 1. In 1862, after some preliminary investigations during the preceding year, Professor J. S. HUBBARD began at the Naval Observatory a series of observations of *α Lyrae* with the Prime Vertical Transit Instrument. The purpose of these observations was to correct the assumed values of the constants of aberration and nutation, and to determine the annual parallax of this star. Professor HUBBARD died in August, 1863. The observations were continued under the direction of Professor SIMON NEWCOMB, who had been an assistant in the observations from May, 1862. Professor WILLIAM HARKNESS became an assistant on this instrument in August, 1862. The observations were carried on by Professors NEWCOMB and HARKNESS until August, 1865, when Professor HARKNESS was detached from the Observatory, and I took his place as assistant until the close of the observations in April, 1867. These observations do not, therefore, extend over sufficient time to give a good correction to the constant of nutation.

The methods of observing and reducing were those of W. STRUVE, as is shown by the following extract from the annual volume of the Observatory for 1862. Introduction, p. xxxv.

"The diaphragm contains a vertical and a pair of close horizontal wires, which cross in the center of the field. On each side of the vertical wire, and at equal distances from it, there is a system of seven close wires; these are used in observing transits. There is also a vertical micrometer wire which is carried by a screw. In April, one revolution of the screw was found to be equal to 25″.969.

The method of observing is as follows: The telescope having been directed to the place of the star before transit over the east vertical, four or six level-readings are taken, the level-tube being reversed upon the axis after each reading. The times of transit over the seven wires first reached by the star are then noted, the instrument is reversed, and the transits over the same wires, now upon the opposite side of the field, are noted in reverse order. The level is again read, with precautions as before. Upon arrival of the star near the west vertical, the same process is repeated, and the telescope returns by the second reversal to its original position.

In observing *α Lyrae* the lateral motion of the star is so slow that it is found practicable to make a part of the level-readings during the actual observations, *i.e.*, between transits over successive wires. Thus, as one or two readings are taken beforehand, at least three obtained during the star's passage, and the remaining one or two before reversal, the observation of level-error is strictly simultaneous with that of transit, and the readings obtained are for precisely those portions of the pivots which are used.

In reducing the observations the transits over each wire have been treated separately according to the method and formulas of STRUVE (*Astr. Nachr.*, XX, p. 210). These formulas are as follows:

Denoting by δ and φ the declination of the star and the latitude of the instrument, by t and t_1 the observed times of the star's transit over a given wire in the east vertical before and after reversal of the instrument, and by t' and t'_1 the corresponding times at the west vertical, and putting

$$s = \tfrac{1}{4}\left[(t'_1-t) + (t'-t_1)\right]$$
$$u = \tfrac{1}{4}\left[(t'_1-t) - (t'-t_1)\right]$$

we have

$$\tan\delta = \tan\varphi \cos s \cos u.$$

The values of $\cos s$ and $\cos u$ are computed separately for each wire, and the mean result multiplied by the constant $\tan\varphi$. The instrument being forty-five feet south of the center of the pier of the mural circle, the latitude of the former is assumed

$$38^\circ\ 53'\ 38''.80$$

The correction for level is given by the formula:

$$d\delta = b \sin 2\delta \operatorname{cosec} 2\varphi$$

or, for *α Lyrae*, $\quad = 0''.984\, b.$

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The intervals of the wires, or their collimation, if either be desired, may be computed by the formula:

$$\sin \text{int.} = \cos \delta \sin \varphi \sin s \sin u.$$

The error in azimuth of the axis is found by comparing the mean of the observed transits east and west, corrected for clock-error, with the tabular right-ascension of the star. The corresponding correction of declination is:

$$d'\delta = \tfrac{1}{4}\, a^2 \sin 1'' \sin 2\delta \operatorname{cosec} \varphi.$$

This correction was found to be sensible for the first few days of observation only.

In the printed observations the headings of the several columns indicate sufficiently the quantities therein shown, and therefore require no special explanation, except that in the reduction to 1860.0 the daily change of declination of the star arising from precession and proper motion is assumed to be

$$+0''.008455 + 0''.0000079\,(t—1860).\text{"}$$

This corresponds to the annual proper motion found by Peters,

$$0''.2792.$$

§ 2. As *α Lyrae* at its transit passed south of the zenith by less than a quarter of a degree, it was assumed that the error of azimuth would generally be insensible. The error of collimation was eliminated by reversal, and the error of level was the only one to be feared. The striding level was reground by Mr. Würdemann, and appears to have been excellent; and, as shown by the above extract, great care was given to the determination of this correction. Until 1865 the observations were reduced to 1860.0, and during the rest of the time to 1870.0, according to the custom then followed at the Naval Observatory. This reduction was computed for every tenth day, and interpolated for the time of observation.

Several years ago, on reducing some equatorial observations for the parallax of this star, I made a careful revision of the formulas employed in reducing the prime-vertical observations, and of the numerical work, and was convinced that these formulas and reductions are essentially correct. However, a slight examination of the declinations found at different seasons of the year showed that, from the entire series, a small negative parallax of the star would result. There were some unfortunate circumstances about the position of the instrument and the construction of the piers; and at that time it seemed to me not worth while to undertake a discussion of these observations. But after a further experience of the difficulty of determining quantities so small as a tenth of a second of arc, it seems to me desirable that such a series of observations, designed by an accomplished astronomer, and made with great care during five years, should be discussed for the purpose of ascertaining what result they will furnish for the constant of aberration. I have therefore undertaken the work of determining the value of this constant and the parallax of the star from these observations.

Soon after beginning the observations, a system of assigning weights was adopted by the observers; thus 5 would denote a perfect condition of the image, 3 an average condition, and 1 a very poor condition. These weights were assumed to depend entirely on the condition of the images. As the observation was a perfectly symmetrical one, it is doubtful whether the equation of condition should be weighted according to the preceding system. This doubt is confirmed by a comparison of the weights and notes of the observers with the results of the reduction. The following are examples:

1863 December 15. Note: — "Observation not worth a curse." Weights ½ and 2.

1866 April 9. Note: — "I consider the independent value of the result of the preceding to be precisely zero, owing to the change of aspect of the star between the verticals: 1st vertical a mass of moving points; 2d vertical well defined." Weights 2 and 3.

The reduction of these observations shows that the results are in good agreement with the mean of the observations. There seems to be a compensation in the case of poor images that is not recognized by this method of weighting. Probably this arises from the greater care that is given to the work when the images are unsteady and poor.

§ 3. *Instrumental Corrections.* The collimation of the telescope would be eliminated by reversal, provided it remained constant during the time of an observation, which was about 68 minutes. Throughout these observations this correction was kept small, and it is assumed to be eliminated by the method of observing.

The level-error is the most important. The method described above for determining this error was followed until 1865. From the beginning of this year, the level was not raised from the axis during an observation, and was read but once in each position of the instrument. This method was adopted from Struve, and seems to give good results. The probable error of a single level-determination was $\pm 0''.084$. There are a few cases where a large change in the length of the bubble is shown, and which might be better explained by repeated readings. I have made but one change in these reductions. On Feb. 20, 1866, the level correction is assumed to be $+0''.40$ instead of $+0''.15$. The level itself appears to have been an excellent instrument. It was examined again at the close of the observations, and the value of a division was found to be $1''.029$.

The error of azimuth was assumed to be insensible, except for the first five observations, March 25 to April 11, 1862. To these a correction of $+0''.15$ was applied on account of azimuth. Since *α Lyrae* passed so near the zenith of the instrument it would require considerable deviation of the

telescope from the prime vertical to produce a sensible error on account of azimuth. A deviation from this plane is shown by comparing the mean of the observed transits, corrected for error of clock, with the right-ascension of the star. If we call this difference τ, the declination observed in the meridian δ, and the declination actually observed δ', we have

$$\tan(90^\circ - \delta') \cos\tau = \tan(90^\circ - \delta),$$

or

$$\frac{\tan\delta}{\tan\delta'} = \frac{1}{\cos\tau}$$

Subtracting unity from both sides of this equation, and reducing, we have

$$\sin(\delta - \delta') = \sin\tfrac{1}{2}\tau^2 .\ 2\sin\delta\cos\delta',$$

or with sufficient accuracy

$$\delta = \delta' + \sin\tfrac{1}{2}\tau^2 \sin 2\delta \operatorname{cosec} 1''.$$

For $\delta = +38^\circ\ 39'.6$, this formula gives the following table of corrections for azimuth with the argument τ.

Correction $= [5.3037]'' \sin\frac{1}{2}\tau^2$.

τ	Corr.	τ	Corr.	τ	Corr.
s	"	s	"	s	"
1	0.000	11	0.032	21	0.117
2	0.001	12	0.038	22	0.129
3	0.002	13	0.045	23	0.141
4	0.004	14	0.052	24	0.153
5	0.007	15	0.060	25	0.166
6	0.010	16	0.068	26	0.180
7	0.013	17	0.077	27	0.194
8	0.017	18	0.086	28	0.209
9	0.022	19	0.096	29	0.224
10	0.027	20	0.106	30	0.239

The reductions being carried out to hundredths of a second of arc, the correction for azimuth becomes sensible for $\tau = 5^s$. As there may be some doubt whether the instrument was always kept sufficiently near the plane of the prime vertical, I have collected all the determinations of the clock-error which enable us to find τ. These are as follows:

1862 April 11	$\tau = 23^s.6$:	Instrument adjusted.
1863 Mar. 31	" = 4.3 :	Adjusted azimuth and collim.
1863 Sept. 23	" = 3.5	
1863 Nov. 4	" = 9.2	
1863 Nov. 13	" = 4.5	
1863 Nov. 18	" = 3.4	
1863 Dec. 1	" = 3.5	
1863 Dec. 26	" = 4.[illegible]	
1864 Jan. 15	" = 4.5	
1864 Feb. 9	" = 2.6	
1864 Feb. 23	" = 3.0	
1864 July 4	" = 4.0	
1864 July 23	" = 4.3	
1864 Aug. 5	$\tau = 1^s.4$	
1864 Sept. 10	" = 3.5	
1864 Nov. 23	" = 0.0	
1865 July 3	" = 0.2	
1865 Aug. 11	" = 0.0	
1865 Sept. 19	" = 3.9	
1866 May 21	" = 2.8	
1866 June 21	" = 1.2	
1866 Oct. 8	" = 0.0	

It will be seen that after the adjustment of the instrument in April, 1862, the values of τ, with one exception, give no sensible corrections for azimuth. Still, it would be desirable that a more continuous examination of this correction should be made, and that the azimuth at the time of observation should be beyond doubt.

§ 4. The following is the assumed form of the equation of condition:

$$x + by + cz + n = 0$$

where

$x =$ correction to the assumed declination of the star,
$y =$ the annual parallax of the star,
$z =$ correction to the assumed constant of aberration,
$n =$ difference of an assumed declination and the observed value.

The coefficients b and c are found from the expressions:

$$b = R\, a \cos(\odot + A)$$
$$c = \quad a \sin(\odot + A).$$

R is the radius vector of the earth, and $\odot$ is the longitude of the sun. The auxiliary quantities are computed from the equations:

$$a \sin A = \cos\varepsilon \sin\alpha \sin\delta - \sin\varepsilon\cos\delta$$
$$a \cos A = -\cos\alpha \sin\delta,$$

in which ε is the obliquity of the ecliptic, and α and δ are the right-ascension and declination of the star. These auxiliary quantities in the case of α *Lyrae* are as follows:

	log a	A
		° '
1862	9.9458	264 17.4
1863	9.9458	264 17.0
1864	9.9458	264 16.7
1865	9.9458	264 16.4
1866–67	9.9458	264 16.1

The following tables contain the equations of condition. The first column gives the running number of the equation; the second column, the date; and the third column, the seconds of the observed declination of the star. Then follow the equations. The last column gives the residuals, which were found by substituting the values of the unknown quantities resulting from the least-square solution in each equation. The quantities of the third column will be found in the volumes of the Naval Observatory, 1862–1867.

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1862.

No.	Date.	Decl.	Equations.	Resid.
		"	"	"
1	Mar. 25	20.52	x —0.003y —0.883z —0.28 = 0	—0.23
2	26	19.93	+0.013 —0.883 +0.31 = 0	+0.36
3	Apr. 2	20.06	+0.119 —0.875 +0.18 = 0	+0.24
4	3	19.91	+0.134 —0.872 +0.33 = 0	+0.39
5	11	20.61	+0.252 —0.847 —0.37 = 0	—0.30
6	15	20.54	+0.310 —0.827 —0.30 = 0	—0.23
7	16	20.56	+0.324 —0.822 —0.32 = 0	—0.25
8	17	20.31	+0.338 —0.817 —0.07 = 0	0.00
9	22	20.17	+0.407 —0.785 +0.07 = 0	+0.15
10	29	20.52	+0.486 —0.732 —0.28 = 0	—0.20
11	May 6	20.31	+0.582 —0.668 —0.07 = 0	+0.01
12	7	20.46	+0.594 —0.659 —0.22 = 0	—0.14
13	8	20.08	+0.604 —0.649 +0.16 = 0	+0.24
14	9	20.10	+0.616 —0.638 +0.14 = 0	+0.22
15	11	20.12	+0.637 —0.631 +0.12 = 0	+0.20
16	12	20.30	+0.647 —0.607 —0.06 = 0	+0.02
17	16	20.30	+0.688 —0.562 —0.06 = 0	+0.02
18	19	19.94	+0.716 —0.528 +0.30 = 0	+0.38
19	21	20.96	+0.734 —0.504 —0.72 = 0	—0.68
20	25	19.88	+0.766 —0.453 +0.36 = 0	+0.44
21	27	20.50	+0.781 —0.429 —0.26 = 0	—0.18
22	28	20.49	+0.789 —0.416 —0.25 = 0	—0.17
23	June 6	20.33	+0.844 —0.295 —0.09 = 0	—0.01
24	8	19.90	+0.854 —0.267 +0.34 = 0	+0.42
25	10	20.49	+0.863 —0.238 —0.25 = 0	—0.18
26	12	20.12	+0.871 —0.210 +0.11 = 0	+0.18
27	13	20.08	+0.874 —0.196 +0.16 = 0	+0.23
28	15	19.84	+0.880 —0.167 +0.40 = 0	+0.47
29	16	20.40	+0.884 —0.153 —0.16 = 0	—0.09
30	17	20.21	+0.887 —0.139 +0.03 = 0	+0.10
31	18	20.59	+0.888 —0.124 —0.35 = 0	—0.28
32	19	20.38	+0.891 —0.109 —0.14 = 0	—0.07
33	24	20.21	+0.897 —0.036 +0.03 = 0	+0.09
34	25	20.76	+0.897 —0.021 —0.52 = 0	—0.46
35	26	20.37	+0.898 —0.007 —0.13 = 0	—0.07
36	27	19.90	+0.898 +0.008 +0.34 = 0	+0.40
37	July 3	20.55	+0.893 +0.095 —0.31 = 0	—0.26
38	4	20.10	+0.891 +0.109 +0.14 = 0	+0.19
39	11	20.01	+0.871 +0.211 +0.23 = 0	+0.27
40	12	20.06	+0.867 +0.225 +0.18 = 0	+0.22
41	14	20.54	+0.859 +0.253 —0.30 = 0	—0.26
42	21	20.29	+0.823 +0.350 —0.05 = 0	—0.32
43	25	19.91	+0.796 +0.408 +0.33 = 0	+0.35
44	28	20.20	+0.775 +0.441 +0.04 = 0	+0.06
45	29	20.41	+0.769 +0.454 —0.17 = 0	—0.15
46	30	20.62	+0.760 +0.466 —0.38 = 0	—0.36
47	Aug. 1	19.98	+0.744 +0.490 +0.26 = 0	+0.27
48	2	20.82	+0.735 +0.503 —0.58 = 0	—0.57
49	4	20.31	+0.717 +0.527 —0.07 = 0	—0.06
50	6	20.28	+0.699 +0.551 —0.04 = 0	—0.04
51	11	20.36	+0.649 +0.607 —0.12 = 0	—0.12
52	12	20.41	+0.639 +0.617 —0.17 = 0	—0.17
53	13	20.28	+0.628 +0.628 —0.04 = 0	—0.04
54	15	20.51	+0.606 +0.648 —0.27 = 0	—0.28
55	18	20.49	+0.572 +0.677 —0.25 = 0	—0.26
56	19	20.32	+0.561 +0.687 —0.08 = 0	—0.10
57	28	20.36	+0.449 +0.762 —0.12 = 0	—0.15
58	Sept. 5	20.26	+0.340 +0.815 —0.02 = 0	—0.07
59	8	20.12	+0.299 +0.831 +0.12 = 0	+0.07

1862.

No.	Date.	Decl.	Equations.	Resid.
		"	"	"
60	Sept. 19	20.06	x +0.138y +0.872z +0.18 = 0	+0.12
61	22	19.49	+0.093 +0.878 +0.75 = 0	+0.68
62	23	19.79	+0.078 +0.879 +0.45 = 0	+0.38
63	25	20.16	+0.048 +0.882 +0.08 = 0	+0.01
64	Oct. 3	19.59	—0.073 +0.879 +0.65 = 0	+0.57
65	6	20.10	—0.118 +0.875 +0.14 = 0	+0.06
66	7	20.60	—0.133 +0.872 —0.36 = 0	—0.44
67	8	20.01	—0.148 +0.871 +0.23 = 0	+0.14
68	9	20.11	—0.163 +0.868 +0.13 = 0	+0.04
69	16	20.03	—0.266 +0.841 +0.21 = 0	+0.12
70	17	19.85	—0.280 +0.837 +0.39 = 0	+0.30
71	18	19.98	—0.294 +0.832 +0.26 = 0	+0.17
72	20	20.16	—0.322 +0.821 +0.08 = 0	—0.02
73	21	20.05	—0.336 +0.816 +0.19 = 0	+0.09
74	22	20.35	—0.351 +0.810 —0.11 = 0	—0.21
75	23	20.56	—0.365 +0.804 —0.32 = 0	—0.42
76	24	19.97	—0.378 +0.796 +0.27 = 0	+0.17
77	27	20.34	—0.419 —0.776 —0.10 = 0	—0.20
78	29	19.77	—0.445 +0.761 +0.47 = 0	+0.37
79	31	20.20	—0.471 +0.744 +0.04 = 0	—0.06
80	Nov. 10	20.27	—0.591 +0.651 —0.03 = 0	—0.14
81	13	19.98	—0.623 +0.619 +0.26 = 0	+0.15
82	15	20.25	—0.644 +0.596 —0.01 = 0	—0.12
83	22	20.28	—0.711 +0.511 —0.04 = 0	—0.14
84	24	20.15	—0.727 +0.486 +0.09 = 0	—0.02
85	Dec. 2	20.38	—0.787 +0.377 —0.14 = 0	—0.24
86	4	20.14	—0.799 +0.349 +0.10 = 0	0.00
87	10	20.41	—0.830 +0.261 —0.17 = 0	—0.27
88	11	20.29	—0.834 +0.246 —0.05 = 0	—0.15
89	12	20.28	—0.839 +0.231 —0.04 = 0	—0.14
90	15	20.32	—0.849 +0.185 —0.08 = 0	—0.17
91	18	20.02	—0.857 +0.140 +0.22 = 0	+0.13
92	20	20.17	—0.862 +0.109 +0.07 = 0	—0.02
93	29	20.13	—0.868 —0.033 +0.11 = 0	+0.03

1863.

No.	Date.	Decl.	Equations.	Resid.
		"	"	"
1	Jan. 1	20.07	x —0.872y —0.094z +0.15 = 0	+0.23
2	2	20.61	—0.862 —0.110 —0.39 = 0	—0.31
3	4	20.21	—0.857 —0.141 +0.01 = 0	+0.08
4	16	20.14	—0.809 —0.322 +0.08 = 0	+0.11
5	30	20.14	—0.707 —0.514 +0.08 = 0	+0.07
6	Feb. 3	20.22	—0.670 —0.563 0.00 = 0	—0.03
7	6	20.63	—0.640 —0.599 —0.41 = 0	—0.45
8	9	20.39	—0.609 —0.632 —0.17 = 0	—0.22
9	12	20.41	—0.576 —0.663 —0.19 = 0	—0.24
10	20	20.40	—0.479 —0.738 —0.18 = 0	—0.26
11	Mar. 2	20.52	—0.345 —0.811 —0.30 = 0	—0.41
12	4	20.27	—0.317 —0.823 —0.05 = 0	—0.16
13	8	20.34	—0.260 —0.843 —0.12 = 0	—0.24
14	11	20.15	—0.216 —0.856 +0.07 = 0	—0.06
15	13	20.16	—0.186 —0.863 +0.06 = 0	—0.07
16	26	20.02	+0.009 —0.883 +0.20 = 0	+0.04
17	29	19.64	+0.055 —0.881 +0.58 = 0	+0.41

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1863.

No.	Date.	Decl.	Equations.				Resid.
		″			″		″
18	Mar. 31	19.83	x+0.085y	—0.879z	+0.39	=0	+0.22
19	Apr. 2	19.72	+0.115	—0.875	+0.50	=0	+0.33
20	3	19.41	+0.130	—0.873	+0.81	=0	+0.64
21	5	19.63	+0.160	—0.868	+0.59	=0	+0.42
22	9	19.96	+0.220	—0.856	+0.26	=0	+0.08
23	10	20.12	+0.234	—0.851	+0.10	=0	—0.08
24	30	20.13	+0.508	—0.726	+0.09	=0	—0.10
25	May 1	19.95	+0.520	—0.717	+0.27	=0	+0.08
26	4	19.58	+0.556	—0.690	+0.64	=0	+0.45
27	10	19.86	+0.624	—0.630	+0.36	=0	+0.17
28	11	19.77	+0.635	—0.620	+0.45	=0	+0.26
29	14	20.23	+0.667	—0.588	—0.01	=0	—0.20
30	15	19.94	+0.676	—0.577	+0.28	=0	+0.10
31	22	20.00	+0.741	—0.494	+0.22	=0	—0.04
32	31	20.47	+0.809	—0.380	—0.25	=0	—0.42
33	June 7	20.20	+0.848	—0.284	+0.02	=0	—0.13
34	8	20.31	+0.854	—0.270	—0.09	=0	—0.24
35	12	20.27	+0.871	—0.214	—0.05	=0	—0.19
36	14	20.35	+0.877	—0.185	—0.13	=0	—0.27
37	17	20.22	+0.910	—0.142	0.00	=0	—0.14
38	July 8	20.15	+0.882	+0.164	+0.07	=0	—0.01
39	Sept. 4	20.51	+0.358	+0.808	—0.29	=0	—0.19
40	5	20.58	+0.344	+0.814	—0.36	=0	—0.26
41	14	20.40	+0.215	+0.857	—0.18	=0	—0.06
42	15	20.23	+0.201	+0.860	—0.01	=0	+0.11
43	16	20.41	+0.186	+0.864	—0.19	=0	—0.06
44	17	20.25	+0.171	+0.867	—0.03	=0	+0.10

1863.

No.	Date.	Decl.	Equations.				Resid.
		″			″		″
45	Sept. 21	20.32	x+0.112y	+0.876z	—0.10	=0	+0.04
46	22	20.58	+0.097	+0.878	—0.36	=0	—0.22
47	23	20.05	+0.081	+0.879	+0.17	=0	+0.31
48	26	20.20	+0.036	+0.882	+0.02	=0	+0.17
49	30	20.52	—0.024	+0.882	—0.30	=0	—0.15
50	Oct. 9	20.06	—0.159	+0.868	+0.16	=0	+0.32
51	12	20.18	—0.204	+0,859	+0.04	=0	+0.21
52	17	20.57	—0.276	+0.838	—0.35	=0	—0.18
53	Nov. 4	20.24	—0.517	+0.712	—0.02	=0	+0.16
54	7	20.44	—0.554	+0.683	—0.22	=0	—0.04
55	13	20.22	—0.621	+0.622	0.00	=0	+0.18
56	14	20.26	—0.631	+0.610	—0.04	=0	+0.14
57	17	20.71	—0.661	+0.576	—0.49	=0	—0.32
58	18	20.01	—0.671	+0.564	+0.21	=0	+0.38
59	20	20.26	—0.691	+0.540	—0.04	=0	+0.13
60	26	20.17	—0.742	+0.463	+0.05	=0	+0.21
61	30	20.83	—0.772	+0.409	+0.61	=0	—0.45
62	Dec. 1	20.16	—0.778	+0.395	+0.06	=0	+0.21
63	3	20.37	—0.791	+0.366	—0.15	=0	0.00
64	4	20.68	—0.797	+0.352	—0.46	—0	—0.31
65	7	20.05	—0.815	+0.309	+0.17	=0	+0.31
66	8	20.57	—0.819	+0.294	—0.35	=0	—0.21
67	10	20.27	—0.829	+0.265	—0.05	=0	+0.09
68	15	20.45	—0.849	+0.189	—0.23	=0	—0.10
69	24	20.33	—0.867	+0.049	—0.11	=0	—0.01
70	26	20.28	—0.868	+0.019	—0.06	=0	+0.04
71	29	20.32	—0.868	—0.028	—0.10	=0	—0.01

(To be continued.)

ON THE VARIABLE STAR *T VULPECULAE*, 7483

BY EDWIN F. SAWYER.

From my observations, 130 in number, of this star, extending from 1885 October 25 to 1887 January 27, the following times of maxima and minima have been determined. The comparisons in the column O—C are with Mr. CHANDLER'S elements, published in No. 145 of this Journal.

OBSERVED MAXIMA.

E	Camb. M.T.	Wt.	O—C
			d
— 2	1885 Oct. 24.65	1	—0.13
— 1	29.90	1	+0.68
0	Nov. 2.28	8	—0.38
+ 2	11.75	2	+0.22
3	16.08	2	+0.11
4	20.49	1	+0.09
5	24.86	1	+0.02
6	29.50	1	+0.22
7	Dec. 3.94	1	+0.22
9	12.77	2	+0.18
10	17.52	2	+0.49
11	21.59	1	+0.13
13	30.39	2	+0.05
16	1886 Jan. 12.84	2	+0.19
17	17.25	1	+0.17
18	21.83	1	+0.31
19	26.25	1	+0.29
58	July 18.33	1	+0.34

OBSERVED MINIMA.

E	Camb. M.T.	Wt.	O—C
			d
2	1885 Nov. 10.85	2	+0.38
3	14.97	2	+0.06
6	28.14	2	—0.08
7	Dec. 2.39	2	—0.27
8	6.96	3	—0.13
9	11.24	1	—0.29
10	15.74	2	—0.23
11	20.24	1	—0.16
12	24.23	1	—0.60
13	29.25	2	—0.03
14	1886 Jan. 2.40	1	—0.31
15	6.82	2	—0.33
16	11.29	2	—0.30
17	15.77	2	—0.25
18	20.60	1	+0.14
52	June 19.89	1	—0.42
59	July 21.05	2	—0.32
60	25.50	2	—0.31

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Observed Maxima.

E	Camb. M.T.	Wt.	O—C
59	1886 July 22.42	1	—0.01 d
60	27.28	1	+0.41
61	31.75	2	+0.45
62	4.42	1	—0.32
65	18.34	1	+0.29
66	22.39	2	—0.10
67	27.33	1	+0.41
68	Sept. 1.16	1	+0.80
72	18.30	1	+0.19
75	Oct. 1.64	2	+0.22
76	6.23	1	+0.38
78	15.02	1	+0.29
79	19.36	2	+0.20
80	23.61	2	+0.01
82	Nov. 1.32	1	—0.16
83	5.87	1	—0.04
85	14.98	2	+0.19
86	19.70	1	+0.48
87	23.20	1	—0.46
88	28.00	1	—0.10
89	Dec. 2.50	2	—0.03
91	11.29	1	—0.12
92	15.95	1	+0.11
93	20.23	1	—0.05
94	25.27	1	+0.55
96	1887 Jan. 2.69	2	+0.10
98	11.46	2	0.00
+99	16.25	1	+0.35

Observed Minima.

E	Camb. M.T.	Wt.	O—C
61	1886 Aug. 30.63	2	+0.39 d
66	21.71	1	+0.28
67	24.90	1	—0.96
73	Sept. 21.38	2	—0.10
74	25.18	1	—0.74
75	29.72	1	—0.64
76	Oct. 4.76	2	—0.04
77	9.43	1	+0.20
80	22.61	2	+0.07
81	26.56	1	—0.42
83	Nov. 4.27	1	—0.59
84	8.91	2	—0.38
86	18.02	1	—0.14
87	22.32	1	—0.28
88	27.12	2	+0.08
89	Dec. 1.26	1	—0.21
90	5.33	1	—0.58
91	9.84	2	—0.51
92	14.26	1	—0.52
93	18.75	2	—0.47
94	22.87	1	—0.79
95	28.10	2	+0.01
97	1887 Jan. 5.57	1	—0.40
98	10.25	1	—0.15
99	14.26	1	—0.58
100	18.27	1	—1.01
102	27.28	1	—0.87

From the residuals O—C for the maxima, using the indicated weights, we find, by the method of least squares, the corrections to the assumed elements and their probable errors,

$$\text{Correction to epoch} \quad +0^{d}.114 \quad \pm 0^{d}.048$$
$$\text{" \quad period} \quad +0^{m}.43 \quad \pm 1^{m}.09$$

The probable error of a determination of a single maximum of weight unity, is $\pm 0^{d}.22$, or one of weight 2, is $\pm 0^{d}.16$.

Treating the minima in the same way, we find

$$\text{Correction to epoch} \quad -0^{d}.020 \quad \pm 0^{d}.048$$
$$\text{" \quad period} \quad -5^{m}.8 \quad \pm 1^{m}.12$$

The probable error of a determination of a single minimum of weight unity, is $\pm 0^{d}.234$, or of weight 2, is $\pm 0^{d}.166$.

It will be seen that the correction to the period deduced from the maxima is much smaller than its probable error. This fact, no less than the opposite sign of this correction when deduced from the mimima, indicates that the value is not trustworthy.

The light-scale used in the reduction of the observations, and in the formation of the following light-table, is

	DM.	α 1855.0	δ 1855.0	Light
a =	DM. 27° 3911	20ʰ 48ᵐ 24ˢ	+27° 30′.0	21.4
b =	" 25 4302	30 54	25 57.5	19.0
c =	" { 31 4159	31 38	31 4.0 }	15.0
	31 4160	31 39	31 1.0 }	
c′ =	DM. 31° 4181	20ʰ 35ᵐ 11ˢ	+31° 47′.5	13.1
d =	" 29 4121	33 1	29 49.6	9.3
e =	" 27 3909	48 13	27 58.3	1.8

Cambridgeport, 1888 *January* 20.

Mr. Chandler desires me to say that the places of these stars on page 2 of Volume VII are for 1855.0, not for 1885.0.

The form of the light-curve shows clearly that only the maxima are suited for the sharp determination of the period, since the flatness of the curve near minimum precludes any great precision in the assignment of that phase.

Light Table.

Time from Max.	Light	Time from Max.	Light
—1.35 d	5.1	+1.00 d	12.4
1.25	5.2	1.25	10.7
1.00	5.5	1.50	8.8
0.75	7.2	1.75	7.4
0.50	10.4	2.00	6.5
0.25	16.4	2.25	5.9
0.00	17.6	2.50	5.5
+0.25	17.0	2.75	5.2
0.50	15.4	3.00	5.1
0.75	13.9	3.10	5.1

The large negative residuals, shown in the observations of minimum, would indicate that the increase of light is somewhat less rapid than found by Mr. Chandler from his observations; in fact, the light-curve gives the duration of increase as 1.35 days, and that of decrease 3.10 days, while Mr. Chandler's results were 1.060 days and 3.337 days, respectively.

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OBSERVATIONS OF COMET 1888 *a*,

MADE AT THE U.S. NAVAL OBSERVATORY, WITH THE 9.6 INCH EQUATORIAL

By Prof. E. FRISBY.

[Communicated by the Superintendent.]

1888 Washington M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
March 17 17 18 48					21 16 32	—14 47.1	n9.598	0.652
18 17 10 34	1	25 , 5	+1 49.74	— 20.0	21 19 52.7	—13 21 52.5	n9.633	0.781
29 17 15 27	2	13 , 3	+0 7.89	+ 7 15.8	21 55 12.0	+ 0 48 3.6	n9.607	0.739
30 16 24 4	3	5 , 1	+7 55.18	+ 4 22.0	21 57 51.3	+ 1 54 7.3	n9.643	0.737
30 16 24 4	4	5 , 1	—3 4.61	+ 0 32.3	21 57 51.7	+ 1 54 7.7	"	"
30 16 39 22	5	10 , 2	+4 7.14	+14 0.2	21 57 53.7	+ 1 54 55.9	"	"
30 16 39 22	4	10 , 2	—3 2.72	+ 1 19.0	21 57 53.6	+ 1 54 53.9	"	"

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 18 4.19	—1.25	—13 21 29.6	—2.9	½(Yarnall+Gould), 18 *Aquarii*
2	21 55 5.29	—1.16	+ 0 40 55.5	—7.7	½(Lamont+Weisse)
3	21 49 57.15	—1.01	+ 1 49 51.0	—6.4	¼(Weisse+Lamont+2 Grant)
4	22 0 57.26	—1.05	+ 1 53 42.0	—6.6	¼(Lamont+Bonn+2 Schj.)
5	21 53 47.55	—1.02	+ 1 41 2.2	—6.5	Bonn VI., +1°. 4568

The observation on the 17th was an instrumental position, and the star *α Aquarii* used for the corrections to the clock and position of the circle. The comparisons were made upon the chronograph and corrected for absolute parallax in both coordinates — all agreeing very closely.

On the 18th, the comet was compared with *F. 18 Aquarii*, whose position from the two catalogues agrees within 0s.03 and 0″.1.

Note. Weisse's place for the comparison-star No. 2 is changed 10°, there being evidently a typographical error.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *a*,

MADE AT THE DUDLEY OBSERVATORY,

By LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s	° ′ ″		
March 17 17 25 56	1	15 , 5	—2 37.45	—1 19.0	21 16 37.2	—14 46 53.8	n9.595	0.817
24 17 23 25	2	21 , 7	+0 37.96	—2 20.9	21 39 9.3	— 5 17 3.6	n9.580	0.795
30 17 0 45	3	18 , 6	—3 1.45	+1 39.0	21 57 54.8	+ 1 55 12.5	n9.596	0.769

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 19 15.92	—1.30	—14 45 32.2	—2.6	Gould G.C. 29356.
2	21 38 32.42	—1.12	— 5 14 37.8	—4.9	Yarnall 9497 and Gould G.C. 29744.
3	22 0 57.28	—1.06	+ 1 53 40.2	—6.7	Albany Zones (4 obs.)

March 17, Head of comet a bright nebulous mass, about 10″ in diameter, and of the fifth magnitude. Daylight illumination of the threads, and observation very sharp.

March 24. Total light of head, as seen without telescope, estimated to be one magnitude fainter than *β Aquarii*. Nucleus sharp and star-like, and of sixth magnitude. Daylight illumination of threads.

March 30. Foggy. The comet appears a full magnitude fainter than the star, which is estimated in the Albany Zones as 7M.2, and in the DM. as 7M.0.

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COMET 1888 *a*.

An orbit and ephemeris for this comet, computed March 21 by Prof. Boss, from FINLAY's observation of February 18, MULLER's of March 13, and his own of March 17, were published and circulated as a *Supplement to No. 168*. Their place is supplied in this number by later values, deduced from longer and more convenient intervals.

ELEMENTS AND EPHEMERIS OF COMET 1888 *a*,

BY LEWIS BOSS.

One of the positions used in my calculation of the elements of Comet 1888 *a*, published in the Supplement to this Journal, No. 168, proved to be in error, and it was with a desire to compute an improved ephemeris that I undertook the present calculation. The positions here used are: Cape, February 18, Albany, March 17, and Albany, March 30. The times and positions were corrected by the help of another set of elements, which differed very little from those here presented, as follows

$$T = 1888 \text{ March } 16.9588 \text{ G.M.T.}$$

$$\left.\begin{aligned} \omega &= 359^\circ\ 49'\ 16'' \\ \Omega &= 245\ \ 30\ \ 29 \\ i &= 42\ \ 16\ \ 50 \end{aligned}\right\} \text{Equinox } 1888.0$$

$$\log q = 9.84450$$

The comparison with the place of March 17 gave:

$$(\mathrm{C-O}) \quad \Delta\lambda \cos\beta = +53''; \quad \Delta\beta = -1''.0$$

As the theoretical ratio of these differences is —49.67, it is evident that the value of the ratio of geocentric distances adopted in the calculation, must have been very nearly correct. In fact, a repetition of the calculation of this quantity, using the above elements, gave a result differing only by 2 in the sixth place of decimals from that which has been adopted. I find the following differences (C—O) between an ephemeris computed from these elements and the observations cited.

		$\Delta\alpha$	$\Delta\delta$
University of Virginia,	March 16.9	+51″	+ 2″
Albany,	17.9	+53	+15
Washington,	18.9	+54	+18
Albany,	24.9	+28	+ 6

This appears to substantiate the corrections of the observations of March 17 and March 30, leaving that of the Cape, February 18, in question. Unless there is a large error in this position, I should be disposed to attribute these residual differences from calculation to the variation of the comet's trajectory from the parabolic form.

Following are the equations of the comet's coordinates.

$$x = r\ 9.898002 \sin(328^\circ\ 11'\ 56'' + v)$$
$$y = r\ 9.999677 \sin(236\ \ 29\ \ \ 4 + v)$$
$$z = r\ 9.787775 \sin(323\ \ 38\ \ \ 1 + v)$$

I suspect that the comet will show greater right-ascensions and declinations by observation than those predicted in the following

EPHEMERIS FOR GREENWICH MIDNIGHT.

	App. R.A. h m s	App. Dec. ° ′ ″	log. r	log. Δ
April 6	22 17 55.7	+ 8 49 58	9.91056	0.08802
8	22 23 51.0	10 43 36	9.92156	0.09766
10	22 29 41.3	12 31 55	9.93287	0.10714
12	22 35 26.5	14 15 10	9.94439	0.11646
14	22 41 6.3	15 53 35	9.95606	0.12560
16	22 46 40.7	17 27 26	9.96778	0.13453
18	22 52 9.3	18 56 56	9.97952	0.14326
20	22 57 32.0	20 22 20	9.99121	0.15176
22	23 2 48.7	21 43 53	0.00283	0.16004
24	23 7 59.5	23 1 50	0.01433	0.16810
26	23 13 4.2	24 16 22	0.02570	0.17593
28	23 18 2.8	25 27 44	0.03691	0.18352
30	23 22 55.3	26 36 5	0.04796	0.19088
May 2	23 27 41.7	27 41 38	0.05881	0.19801
4	23 32 21.7	28 44 33	0.06948	0.20492
6	23 36 56.0	29 45 8	0.07995	0.21158
8	23 41 23.8	30 43 12	0.09022	0.21803
10	23 45 45.4	31 39 12	0.10030	0.22426
12	23 50 0.8	32 33 10	0.11017	0.23027
14	23 54 9.7	33 25 14	0.11984	0.23606
16	23 58 12.3	34 15 29	0.12931	0.24164
18	0 2 8.6	35 4 2	0.13859	0.24701
20	0 5 58.7	35 50 59	0.14768	0.25219

Albany, 1888 *April* 2.

CORRIGENDA.

No. 168, page 191. The reductions to apparent place, for α of the comparison-stars, should be —1ˢ.38, —1ˢ.38, —1ˢ.30; and corresponding changes should be made in the apparent right-ascensions of the comet.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 170.

VOL. VIII. BOSTON, 1888 APRIL 18. NO. 2.

THE CONSTANT OF ABERRATION,

BY PROF. A. HALL.

[Communicated by Capt. R. L. PHYTHIAN, Superintendent Naval Observatory.]

(*Continued.*)

1864.

No.	Date.		Decl.	Equations.			Resid.
			″			″	″
1	Jan.	1	20.69	x —0.864y	—0.091z	—0.45 = 0	—0.42
2		13	20.48	—0.826	—0.275	—0.24 = 0	—0.23
3		15	20.24	—0.816	—0.304	0.00 = 0	0.00
4		22	19.97	—0.773	—0.404	+0 27 = 0	+0.26
5		24	20.22	—0.758	—0.432	+0.02 = 0	+0.00
6		25	20.34	—0.751	—0.445	—0.10 = 0	—0.12
7		26	20.05	—0.743	—0.458	+0.19 = 0	+0.17
8		28	20.15	—0.727	—0.485	+0.09 = 0	+0.06
9	Feb.	4	20.15	—0.663	—0.572	+0.09 = 0	+0.05
10		9	20.30	—0.612	—0.630	—0.06 = 0	—0.11
11		23	19.77	—0.444	—0.761	+0.47 = 0	+0.39
12		25	20.18	—0.417	—0.776	+0.06 = 0	—0.03
13		26	20.03	—0.404	—0.783	+0.21 = 0	+0.12
14	Mar.	1	19.65	—0.349	—0.810	+0.59 = 0	+0.49
15		3	19.80	—0.321	—0.822	+0.44 = 0	+0.34
16		6	19.96	—0.278	—0.837	+0.28 = 0	+0.18
17		11	19.84	—0.205	—0.858	+0.40 = 0	+0.29
18		13	20.32	—0.176	—0.865	—0.08 = 0	—0.20
19	May	9	20.20	+0.622	—0.633	+0.04 = 0	—0.10
20		19	20.19	+0.721	—0.522	+0.05 = 0	—0.09
21		20	20.25	+0.730	—0.509	—0.01 = 0	—0.15
22		22	20.54	+0.747	—0.486	—0.30 = 0	—0.43
23		30	20.24	+0.807	—0 383	0.00 = 0	—0.12
24		31	19.93	+0.813	—0.369	+0.31 = 0	+0.19
25	June	3	20.60	+0.832	—0.329	—0.36 = 0	—0.48
26		7	20.52	+0.852	—0.274	—0.28 = 0	—0.39
27		12	20.36	+0.873	—0.203	—0.12 = 0	—0.23
28		13	19.64	+0.876	—0.189	+0.60 = 0	+0.50
29		15	20.43	+0.882	—0.160	—0.19 = 0	—0.29
30		16	20.50	+0.885	—0.146	—0.26 = 0	—0.36
31		17	20.05	+0.887	—0.131	+0.19 = 0	+0.10
32		20	19.99	+0.893	—0.087	+0.25 = 0	+0.16
33		22	20.22	+0.895	—0.058	+0.02 = 0	—0.07
34		24	20.19	+0.897	—0.029	+0.05 = 0	—0.04
35		27	19.93	+0.898	+0.015	+0.31 = 0	+0.23
36		30	20.37	+0.895	+0.059	—0.13 = 0	—.020
37	July	4	19.89	+0.890	+0.117	+0.35 = 0	+0.28
38		5	20.48	+0.887	+0.132	—0.24 = 0	—0.30

1864.

No.	Date.		Decl.	Equations.			Resid.
			″		″		″
39	July	6	20.17	x +0.886y	+0.147z	+0.07 = 0	+0.01
40		8	19.98	+0.879	+0.175	+0.26 = 0	+0.20
41		9	19.88	+0.877	+0.189	+0.36 = 0	+0.30
42		11	20.64	+0.870	+0.218	—0.40 = 0	—0.45
43		15	20.04	+0.853	+0.274	+0.20 = 0	+0.16
44		16	19.93	+0.849	+0.288	+0.31 = 0	+0.27
45		22	19.95	+0.814	+0.370	+0.29 = 0	+0.26
46		23	20.28	+0.808	+0.383	—0.04 = 0	—0.07
47		25	20.28	+0.795	+0.409	—0.04 = 0	—0.06
48		27	20.33	+0.780	+0.435	—0.09 = 0	—0.11
49		28	20.24	+0.773	+0.448	0.00 = 0	—0.02
50		30	20.09	+0.757	+0.473	+0.15 = 0	+0.14
51	Aug.	1	20.08	+0.740	+0.497	+0.16 = 0	+0.15
52		3	20.36	+0.722	+0.522	—0.12 = 0	—0.12
53		5	20.29	+0.705	+0.545	—0.05 = 0	—0.05
54		9	20.41	+0.666	+0.590	—0.17 = 0	—0.16
55		10	20.30	+0.655	+0.601	—0.06 = 0	—0.05
56		12	19.99	+0.635	+0.623	+0.25 = 0	+0.26
57		15	20.02	+0.601	+0.653	+0.22 = 0	+0.24
58		23	20.71	+0.507	+0.727	—0.47 = 0	—0.43
59		30	20.33	+0.417	+0.781	—0.09 = 0	—0.04
60	Aug.	31	19.69	+0.404	+0.788	+0.55 = 0	+0.61
61	Sept.	2	20.56	+0.376	+0.800	—0.32 = 0	—0.26
62		10	20.11	+0.264	+0.843	+0.13 = 0	+0.20
63		13	20.23	+0.220	+0.856	+0.01 = 0	+0.09
64		17	20.15	+0.161	+0.868	+0.09 = 0	+0.17
65		20	20.23	+0.116	+0.875	+0.01 = 0	+0.10
66		27	20.24	+0.010	+0.883	0.00 = 0	+0.10
67	Oct.	7	20.20	—0.140	+0.872	+0.04 = 0	+0.14
68		10	20.53	—0.185	+0.864	—0.29 = 0	—0.18
69		11	20.18	—0.200	+0.860	+0.06 = 0	+0.17
70		13	20.17	—0.230	+0.852	+0.07 = 0	+0.18
71		14	20.32	—0.244	+0.849	—0.08 = 0	+0.03
72		17	20.11	—0.287	+0.834	+0.13 = 0	+0.24
73		18	20.29	—0.301	+0.829	—0.05 = 0	+0.06
74		19	20.29	—0.315	+0.824	—0.05 = 0	+0.06
75		21	20.10	—0.343	+0.812	+0.14 = 0	+0.25
76	Oct.	25	20.32	—0.398	+0.787	—0.08 = 0	+0.03

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1864.

No.	Date.	Decl.	Equations.			Resid.
		"			"	"
77	Oct. 28	20.51	x—0.438y	+0.765z	—0.27 = 0	—0.16
78	Nov. 1	20.27	—0.490	+0.732	—0.03 = 0	+0.08
79	5	20.67	—0.539	+0.696	—0.43 = 0	—0.32
80	10	20.46	—0.596	+0.645	—0.22 = 0	—0.11
81	11	20.35	—0.607	+0.635	—0.11 = 0	0.00
82	14	20.71	—0.639	+0.602	—0.47 = 0	—0.36
83	23	20.63	—0.723	+0.493	—0.39 = 0	—0.29
84	24	20.38	—0.731	+0.479	—0.14 = 0	—0.04
85	28	20.49	—0.763	+0.426	—0.25 = 0	—0.16
86	29	20.49	—0.770	+0.412	—0.25 = 0	—0.16
87	30	20.43	—0.777	+0.398	—0.19 = 0	—0.10
88	Dec. 12	20.71	—0.841	+0.223	—0.47 = 0	—0.40
89	23	20.60	—0.867	+0.054	—0.36 = 0	—0.31
90	29	19.81	—0.867	—0.041	+0.43 = 0	+0.47

1865.

No.	Date.	Decl.	Equations.			Resid.
		"			"	"
1	Jan. 3	51.19	x—0.858y	—0.134z	+0.03 = 0	+0.19
2	4	51.53	—0.855	—0.149	—0.31 = 0	—0.15
3	10	51.73	—0.835	—0.241	—0.51 = 0	—0.34
4	11	51.41	—0.831	—0.256	—0.19 = 0	—0.02
5	12	51.19	—0.826	—0.271	+0.03 = 0	+0.20
6	15	51.49	—0.811	—0.322	—0.27 = 0	—0.10
7	19	51.20	—0.788	—0.372	+0.02 = 0	+0.19
8	27	51.65	—0.729	—0.482	—0.43 = 0	—0.26
9	Feb. 12	51.26	—0.569	—0.668	—0.04 = 0	+0.11
10	13	51.20	—0.558	—0.678	+0.02 = 0	+0.17
11	19	51.46	—0.485	—0.734	—0.24 = 0	—0.10
12	20	51.18	—0.472	—0.742	+0.04 = 0	+0.18
13	26	51.40	—0.393	—0.788	—0.18 = 0	—0.05
14	Mar. 5	51.22	—0.296	—0.831	0.00 = 0	+0.12
15	6	51.30	—0.281	—0.836	—0.08 = 0	+0.04
16	10	50.95	—0.223	—0.854	+0.27 = 0	+0.38
17	12	51.20	—0.194	—0.861	+0.02 = 0	+0.12
18	16	50.80	—0.134	—0.872	+0.42 = 0	+0.51
19	17	50.99	—0.119	—0.874	+0.23 = 0	+0.32
20	20	51.08	—0.074	—0.879	+0.14 = 0	+0.22
21	Apr. 7	50.86	+0.197	—0.860	+0.36 = 0	+0.39
22	May 7	51.04	+0.597	—0.656	+0.18 = 0	+0.13
23	14	51.40	+0.671	—0.582	—0.18 = 0	—0.25
24	16	51.29	+0.691	—0.559	—0.07 = 0	—0.14
25	24	51.19	+0.761	—0.463	+0.03 = 0	—0.06
26	30	51.28	+0.805	—0.386	—0.06 = 0	—0.17
27	31	51.24	+0.812	—0.373	—0.02 = 0	—0.13
28	June 2	51.26	+0.824	—0.346	—0.04 = 0	—0.15
29	7	51.57	+0.851	—0.277	—0.35 = 0	—0.47
30	9	50.95	+0.860	—0.249	+0.27 = 0	+0.14
31	11	51.27	+0.868	—0.221	—0.05 = 0	—0.18
32	18	51.22	+0.889	—0.120	0.00 = 0	—0.14
33	22	51.45	+0.895	—0.062	—0.23 = 0	—0.38
34	23	51.32	+0.896	—0.047	—0.10 = 0	—0.25
35	28	51.25	+0.897	+0.034	—0.03 = 0	—0.18
36	July 3	51.24	+0.892	+0.099	—0.02 = 0	—0.18
37	5	51.13	+0.888	+0.128	+0.09 = 0	—0.07

1865.

No.	Date.	Decl.	Equations.			Resid.
		"			"	"
38	July 6	51.15	x+0.886y	+0.143z	+0.07 = 0	—0.09
39	7	51.40	+0.883	+0.157	—0.18 = 0	—0.34
40	14	50.91	+0.858	+0.257	+0.31 = 0	+0.15
41	18	51.41	+0.839	+0.312	—0.19 = 0	—0.35
42	20	51.29	+0.828	+0.339	—0.07 = 0	—0.23
43	25	50.84	+0.796	+0.406	+0.38 = 0	+0.22
44	26	50.93	+0.789	+0.419	+0.29 = 0	+0.13
45	28	50.98	+0.774	+0.444	+0.24 = 0	+0.08
46	Aug. 7	50.98	+0.687	+0.565	+0.24 = 0	+0.08
47	8	50.87	+0.678	+0.576	+0.35 = 0	+0.19
48	11	50.59	+0.647	+0.609	+0.63 = 0	+0.48
49	16	50.73	+0.593	+0.660	+0.49 = 0	+0.34
50	Sept. 2	50.53	+0.379	+0.799	+0.69 = 0	+0.57
51	6	50.82	+0.324	+0.822	+0.40 = 0	+0.29
52	11	51.18	+0.252	+0.846	+0.04 = 0	—0.06
53	12	50.99	+0.238	+0.850	+0.23 = 0	+0.13
54	16	50.85	+0.179	+0.864	+0.37 = 0	+0.28
55	19	50.97	+0.134	+0.872	+0.25 = 0	+0.17
56	20	50.99	+0.119	+0.875	+0.23 = 0	+0.15
57	Oct. 20	51.34	—0.326	+0.819	—0.12 = 0	—0.12
58	21	50.88	—0.340	+0.814	+0.34 = 0	+0.34
59	Nov. 1	50.86	—0.486	+0.734	+0.36 = 0	+0.39
60	6	51.09	—0.547	+0.688	+0.13 = 0	+0.18
61	8	51.03	—0.570	+0.668	+0.19 = 0	+0.24
62	9	51.68	—0.582	+0.658	—0.46 = 0	—0.40
63	10	51.30	—0.593	+0.648	—0.08 = 0	—0.02
64	11	51.44	—0 604	+0.637	—0.22 = 0	—0.16
65	13	51.57	—0.625	+0.615	—0.35 = 0	—0.28
66	14	51.52	—0.636	+0.604	—0.30 = 0	—0.23
67	16	51.47	—0.656	+0.581	—0.25 = 0	—0.18
68	17	51.38	—0.666	+0.570	—0.16 = 0	—0.08
69	25	51.46	—0.737	+0.469	—0.24 = 0	—0.14
70	28	51.63	—0.760	+0.429	—0.41 = 0	—0.31
71	Dec. 2	51.35	—0.788	+0.374	—0.13 = 0	—0.02
72	8	51.74	—0.822	+0.287	—0.52 = 0	—0.40
73	14	51.54	—0.847	+0.197	—0.32 = 0	—0.18
74	16	51.21	—0.853	+0.166	+0.01 = 0	+0.15
75	22	51.86	—0.865	+0.073	—0.64 = 0	—0.49
76	23	51.48	—0.866	+0.058	—0.26 = 0	—0.11

1866-1867.

No.	Date.	Decl.	Equations.			Resid.
	1866	"			"	"
1	Jan. 3	51.84	x—0.858y	—0.130z	—0.55 = 0	—0.47
2	7	51.96	—0.847	—0.191	—0.67 = 0	—0.58
3	8	51.88	—0.844	—0.207	—0.59 = 0	—0.50
4	21	51.52	—0.776	—0.397	—0.23 = 0	—0.11
5	31	51.60	—0.696	—0.530	—0.31 = 0	—0.18
6	Feb. 1	51.71	—0.687	—0.542	—0.42 = 0	—0.28
7	4	51.68	—0.658	—0.578	—0.39 = 0	—0.25
8	5	51.49	—0.648	—0.590	—0.20 = 0	—0.06
9	14	51.68	—0.549	—0.686	—0.39 = 0	—0.24
10	15	52.07	—0.537	—0.696	—0.78 = 0	—0.63
11	16	50.96	—0.525	—0.705	+0.33 = 0	+0.48
12	19	51.37	—0.488	—0.732	—0.08 = 0	+0.07

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1866-1867.

No.	Date.		Decl.	Equations.			Resid.
	1866		"			"	"
13	Feb.	20	51.16	x—0.475y	—0.741z	+0.13 = 0	+0.29
14		21	51.20	—0.463	—0.749	+0.09 = 0	+0.24
15		25	51.71	—0.410	—0.780	—0.42 = 0	—0.27
16	Mar.	5	51.15	—0.299	—0.830	+0.14 = 0	+0.29
17		7	51.45	—0.271	—0.840	—0.16 = 0	—0.01
18		8	51.31	—0.256	—0.844	—0.02 = 0	+0.13
19		9	51.68	—0.242	—0.849	—0.39 = 0	—0.24
20		14	51.47	—0.168	—0.866	—0.18 = 0	—0.03
21		16	51.38	—0.138	—0.872	—0.09 = 0	+0.06
22		21	50.83	—0.063	—0.880	+0.46 = 0	+0.60
23		25	51.58	—0.002	—0.883	—0.29 = 0	—0.15
24		26	51.59	+0.013	—0.883	—0.30 = 0	—0.17
25		27	51.37	+0.028	—0.880	—0.08 = 0	+0.05
26	April	1	51.27	+0.104	—0.877	+0.02 = 0	+0.15
27		9	51.67	+0.223	—0.854	—0.38 = 0	—0.27
28		24	51.06	+0.434	—0.770	+0.23 = 0	+0.31
29	May	6	51.18	+0.582	—0.668	+0.11 = 0	+0.16
30		12	51.50	+0.648	—0.607	—0.21 = 0	—0.17
31		14	51.01	+0.669	—0.585	+0.28 = 0	+0.31
32		19	50.72	+0.716	—0.528	+0.57 = 0	+0.59
33		21	51.23	+0.734	—0.504	+0.06 = 0	+0.07
34		22	51.14	+0.743	—0.491	+0.15 = 0	+0.16
35		24	51.41	+0.759	—0.467	—0.12 = 0	—0.11
36		29	51.40	+0.797	—0.402	—0.11 = 0	—0.12
37	June	11	51.33	+0.867	—0.224	—0.04 = 0	—0.08
38		19	51.15	+0.890	—0.109	+0.14 = 0	+0.07
39		20	51.10	+0.892	—0 095	+0.19 = 0	+0.12
40		21	51.25	+0.894	—0.080	+0.04 = 0	—0.02
41		23	51.22	+0.896	—0.051	+0.07 = 0	—0.01
42		25	51.11	+0.897	—0.022	+0.18 = 0	+0.10
43		30	51.69	+0.896	+0.052	—0.40 = 0	—0.49
44	July	2	51.23	+0.894	+0.081	+0.06 = 0	—0.03
45		5	51.38	+0.889	+0.124	—0.09 = 0	—0.19
46		7	51.09	+0.884	+0.153	+0.20 = 0	+0.09
47		11	51.52	+0.871	+0.211	—0.23 = 0	—0.35
48		12	51.15	+0.868	+0.225	+0.14 = 0	+0.02
49		13	51.13	+0.864	+0.239	+0.16 = 0	+0.04
50		14	51.39	+0.859	+0.253	—0.10 = 0	—0 22
51		16	51.54	+0.850	+0.281	—0.25 = 0	—0.38
52		23	51.32	+0.811	+0.376	—0.03 = 0	—0.17
53		26	51.69	+0.791	+0.416	—0.40 = 0	—0.54
54		27	50.91	+0.783	+0.429	+0.38 = 0	+0.24
55		31	51.48	+0.752	+0.479	—0.19 = 0	—0.34
56	Aug.	6	51.12	+0.699	+0.551	+0.17 = 0	+0.01
57		10	50.95	+0.660	+0.595	+0.34 = 0	+0.18
58		15	51.16	+0.607	+0.648	+0.13 = 0	—0.04
59		16	51.18	+0.596	+0.658	+0.11 = 0	—0.06
	1866		"			"	"
60	Aug.	17	51.10	x+0.584y	+0.667z	+0.19 = 0	+0.02
61		18	51.28	+0.573	+0.677	+0.01 = 0	—0.16
62		20	50.96	+0.549	+0.696	+0.33 = 0	+0.16
63		23	51.48	+0.513	+0.722	—0.19 = 0	—0.36
64		30	50.90	+0.423	+0.777	+0.39 = 0	+0.22
65	Sept.	22	50.56	+0.093	+0.878	+0.73 = 0	+0.57
66		24	51.04	+0.063	+0.880	+0.25 = 0	+0.09
67		27	51.26	+0.017	+0.882	+0.03 = 0	—0.13
68	Oct.	3	50.79	—0.073	+0.880	+0.50 = 0	+0.35
69		4	51.04	—0.088	+0.878	+0.25 = 0	+0.10
70		5	51.25	—0.103	+0.877	+0.04 = 0	—0.11
71		6	51.14	—0.118	+0.876	+0.15 = 0	0.00
72		8	50.86	—0.133	+0.873	+0.43 = 0	+0.28
73		15	51.13	—0.251	+0.846	+0.16 = 0	+0.03
74		16	51.47	—0.266	+0.841	—0.18 = 0	—0.31
75		17	51.22	—0.280	+0.837	+0.07 = 0	—0.06
76		19	50.98	—0.309	+0.826	+0.31 = 0	+0.19
77		23	50.94	—0.364	+0.803	+0.35 = 0	+0.24
78	Nov.	2	51.05	—0.496	+0.727	+0.24 = 0	+0.15
79		6	51.22	—0.544	+0.691	+0.07 = 0	—0.01
80		13	51.31	—0.623	+0.618	—0.02 = 0	—0.08
81		21	51.22	—0.710	+0.512	+0.07 = 0	+0.03
82		22	50.72	—0.719	+0.499	+0.57 = 0	+0.53
83		27	50.80	—0.751	+0.446	+0.49 = 0	+0.47
84	Dec.	3	51.09	—0.793	+0.363	+0.20 = 0	+0.19
85		5	51.22	—0.805	+0.334	+0.07 = 0	+0.07
86		10	51.29	—0.830	+0.261	0.00 = 0	—0.01
87		12	51.56	—0.839	+0.231	—0.27 = 0	—0.25
88		19	51.01	—0.860	+0.124	+0.28 = 0	+0.32
89		20	51.46	—0.862	+0 108	—0.17 = 0	—0.13
90		28	51.35	—0.868	—0.017	—0.06 = 0	0.00
	1867						
91	Jan.	3	50.55	—0.859	—0.126	+0.74 = 0	+0.82
92		11	51.63	—0.833	—0.248	—0.34 = 0	—0.24
93		14	51.58	—0.819	—0.293	—0.29 = 0	—0.19
94		16	51.56	—0.809	—0.322	—0.27 = 0	—0.16
95		17	52.20	—0.803	—0.337	—0.91 = 0	—0.85
96		22	51.57	—0.771	—0.408	—0.28 = 0	—0.16
97		23	51.34	—0.764	—0.421	—0.05 = 0	+0.07
98		28	52.11	—0.725	—0.488	—0.82 = 0	—0.69
99	Feb.	6	51.11	—0.640	—0.598	+0.18 = 0	+0.32
100		10	51.24	—0.598	—0.643	+0.05 = 0	+0.19
101		11	51.29	—0.586	—0.653	0.00 = 0	+0.14
102		17	51.33	—0.516	—0.712	—0.04 = 0	+0 11
103		26	51.22	—0.400	—0.785	+0.07 = 0	+0.21
104		27	50.91	—0.386	—0.792	+0.38 = 0	+0.53
105	Mar.	29	50.97	+0.055	—0.881	+0.32 = 0	+0.45
106	April	2	51.47	+0.115	—0.876	—0.18 = 0	—0.06

§ 5. These equations have been solved by dividing them into groups, according to the years, and giving the weight unity to each observation. In this manner the direct solution furnishes the following normals and values of the unknown quantities:

1862. 93 *Observations.*

$$+93.0000.x +23.7970.y +15.7450.z +0''.7300 = 0.$$
$$+23.7970.x +38.9906.y - 7.7521.z -2.7212 = 0.$$
$$+15.7450.x - 7.7521.y +34.7024.z +3.0078 = 0.$$
$$[nn] = 6.2589$$

$$x = -0''.013 \pm 0''.0197$$
$$y = +0.065 \pm 0.0323$$
$$z = -0.066 \pm 0.0327$$
$$[nn.3] = 5.875$$
$$r_1 = \pm 0''.173 \qquad \Sigma pv^2 = 5.893$$

1863. 71 *Observations.*

$$+71.0000.x - 9.4174.y - 2.4722.z -0''.2800 = 0.$$
$$- 9.4174.x +25.3268.y - 5.2638.z +3.7929 = 0.$$
$$- 2.4722.x - 5.2638.y +29.7865.z -5.8619 = 0.$$
$$[nn] = 5.3464$$

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$$x = -0''.005 \pm 0''.0197$$
$$y = -0.115 \pm 0.0336$$
$$z = +0.176 \pm 0.0302$$
$$[nn.3] = 3.879$$
$$r_1 = \pm 0''.161 \qquad \Sigma pv^2 = 3.881$$

1864. 90 *Observations.*

$$+90.0000.x + 11.5040.y + 15.3720.z + 0.4100 = 0.$$
$$+11.5040.x + 40.8390.y + 3.3503.z + 2.7288 = 0.$$
$$+15.3720.x + 3.3503.y + 29.7233.z - 3.3133 = 0.$$
$$[nn] = 5.7433$$
$$x = -0''.017 \pm 0.0183$$
$$y = -0.073 \pm 0.0261$$
$$z = +0.129 \pm 0.0314$$
$$[nn.3] = 5.112$$
$$r_1 = \pm 0''.164 \qquad \Sigma pv^2 = 5.113$$

1865. 76 *Observations.*

$$+76.0000.x + 0.6770.y + 4.1200.z + 0''.0900 = 0.$$
$$+ 0.6770.x + 34.6235.y + 0.4682.z + 6.0334 = 0.$$
$$+ 4.1200.x + 0.4682.y + 24.6637.z + 1.9132 = 0.$$
$$[nn] = 5.7433$$
$$x = +0''.004 \pm 0''.194$$
$$y = -0.173 \pm 0.286$$
$$z = -0.075 \pm 0.341$$
$$[nn\ 3] = 4.554$$
$$r_1 = \pm 0''.168 \qquad \Sigma pv^2 = 4.553$$

1866-67. 106 *Observations.*

$$+106.0000.x - 3.7590.y - 7.4160.z - 0''.3600 = 0.$$
$$- 3.7590.x + 42.7962.y + 7.2235.z + 4.6287 = 0.$$
$$- 7.4160.x + 7.2235.y + 39.8050.z + 7.1038 = 0.$$
$$[nn] = 10.3439$$
$$x = -0''.011 \pm 0''.0193$$
$$y = -0.081 \pm 0.0306$$
$$z = -0.166 \pm 0.0312$$
$$[nn.3] = 8.795$$
$$r_1 = \pm 0''.197 \qquad \Sigma pv^2 = 8.793$$

It will be seen from the values of y that the parallax of the star has a negative value for each of the years except 1862. The mean values of y and z by weight are as follows:

$$y = -0''.079 \quad \pm 0''.0134$$
$$z = +0\ .0055 \ \pm 0\ .0142$$

As the assumed value of the constant of aberration was 20″.4451, we have as the direct result of the 436 observations,

Constant of aberration = 20″.4506 ±0″.0142.

The average probable error of a single observation is ±0″.174.

§6. Since the method of observing on the prime vertical should give the absolute parallax of the star, the negative result indicates some abnormal error in the declinations which has vitiated the parallax. In order to show the dependence of the result for aberration on the parallax of the star, I have made an indirect solution, expressing z in terms of y. We have

1862	$z = +0.3678.y - 0''.0900 \pm 0''.03440$
1863	$z = +0.1883.y + 0.1977 \pm 0.03089$
1864	$z = -0.0511.y + 0.1249 \pm 0.03146$
1865	$z = -0.0176.y - 0.0781 \pm 0.03409$
1866–67	$z = -0.1772.y - 0.1805 \pm 0.03121$

These equations show that the determination of z, or the correction for the constant of aberration, is nearly independent of y, the parallax of the star.

α Lyrae is one of the stars most frequently observed for annual parallax. The following is a collection of the values found by different observers since accurate observations have been made.

Astronomer	Year	Parallax		
		″	″	
Brinkley	1818-1822	+1.138		absolute
Pond	1822-1823	0.0		"
Airy	1836 (Troughton Circle)	+0.233		"
Airy	1836 (Jones Circle)	—0.092		"
W. Struve	1837	+0.262	±0.025	differential
C. A. F. Peters	1842	+0.103	±0.053	absolute
O. Struve	1851-1853	+0.147	±0.009	differential
Johnson	1854-1855	+0.154	±0.046	"
Brünnow	1869	+0.214	±0.009	"
Brünnow	1870	+0.188	±0.033	"
Hall	1880	+0.134	±0.006	"

The values of parallax by the differential method are in good agreement, but the weak point is that most of them depend on the same star of comparison. Of the absolute determinations, that by PETERS is the only one to which much weight can be attached. For use in the preceding equations I adopt the value +0″.15. Substituting this value for y in the equations given above, reducing, and combining by weights, we have,

$$z = +0''.0091 \pm 0''.0144$$

By this solution we have, therefore,

Constant of aberration = 20″.4542 ±0″.0144

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Although there remains some uncertainty about the parallax of the star, I prefer this value of the constant of aberration.

§ 7. The negative parallax of the star, found from the direct solution of the equations of condition, may suggest the question whether such a result would not be avoided by classifying the observations according to the observers. But an examination will show, I think, that the same result will follow from this arrangement, since the observations throughout the year are generally pretty evenly distributed among the observers. In the last set of observations, a little more than one-third of them were made in the winter months, and this may account for the greater probable error of a single observation. Neither will the theoretical ten-month period in the latitude furnish a satisfactory explanation, as may be seen from the grouping of the observations given in *Appendix I*, *Washington Observations*, 1879, p. 63.

The most plausible explanation of the negative parallax seems to me the following. It will be seen that the coefficient of parallax has its maximum values about the first of January and July, that is, at the extremes of annual temperature. This condition results from the position of the star, and increases the difficulty of determining its parallax. Again, the observations in winter were made in daylight, and those of summer at night. This change would produce a difference in the image of the star that might introduce a small constant difference in the declinations. It was assumed, of course, that the symmetry of the method of observing would free the result from errors caused by temperature and the change from daylight to darkness, but I think the assumption is doubtful when the intention is to determine quantities as small as a tenth of a second of arc. The constant of aberration is determined under better conditions, since the greatest values of this coefficient occur in April and October, and the transits would be observed under nearly similar conditions of temperature and aspect of the image.

§ 8. The constant of aberration has an interesting connection with the solar parallax. If we designate by k the number of seconds which light requires to pass over the mean distance of the earth from the sun, by φ the angle whose sine is the eccentricity of the earth's orbit, by M the mean anomaly of the earth, and by t the time, we have by definition

$$\frac{k}{\cos\varphi}\cdot\frac{dM}{dt} = \text{constant of aberration} = c.$$

If v be the velocity of light, a the mean distance of the earth from the sun, R the equatorial radius of the earth, and π the solar parallax, then

$$v = \frac{a}{k}; \qquad a = \frac{R}{\pi};$$

and eliminating k we have

$$\pi'' = \frac{R}{cv\cos\varphi}\cdot\frac{dM}{dt}\times 206265$$

1887 *December* 10.

We have from observation

$\log\dfrac{dM}{dt} = 8.613493$		Hansen
$\log\cos\varphi = 9.999939$		"
$R = 3963.3$ miles		Clarke
$v = 186325$ "		Michelson and Newcomb
$c = 20''.4542 \pm 0''.0144$ (derived above)		

These numbers give for the solar parallax

$$\pi = 8''.810 \pm 0''.0062$$

There are two theoretical corrections to be applied to the constant of aberration. In the first place the motion of a planet is around the center of gravity of the planet and sun, and not around the center of the sun. This correction is

$$\frac{20''.45\times m}{\sqrt{a}}$$

m being the mass of the planet, and a its mean distance from the sun (Bessel, *Fund. Astr.*, p. 132). Since for the earth

$$m = \frac{1}{326800}$$

this correction is $0''.00006$, and can be neglected.

A second correction is required on account of the motion of the solar system in space (Bessel, *Tabb. Reg.*, p. xix). As yet we have only rough determinations of this motion, since at present accurate observations of the stars do not extend over a sufficient interval of time. Struve's estimate of this motion is 1.6 per annum, the mean distance of the earth from the sun being the unit. This motion would give for the correction to the constant of aberration $0''.0005$, as a maximum which could change the position of a star. It is therefore probably too small ever to be recognized by observation. The theory of these corrections has been elaborately discussed by M. Villarceau in the *Conn. des Temps* for 1878, where he has treated also the motion of our sidereal system.

Considering the smallness of these corrections, and the accuracy with which the velocity of light is known, I think the above method of determining the solar parallax is the best that astronomers now have.

For assistance in these reductions I am indebted chiefly to Lieut. Wm. H. Allen, U.S.N. Mr. A. D. Risteen, of the U.S. Coast and Geodetic Survey, wished to work an example in least squares, and he solved gratuitously the equations for 1864, finding the same results as those given above.

In conclusion, I should say that the observing books show that this instrument was cleaned and refittted in 1867, and a new series of observations of *α Lyrae* was begun by Prof. Cleveland Abbe, who had just returned from his astronomical studies at Pulkowa. These observations were soon interrupted by Professor Abbe's removal to Cincinnati to take charge of the Observatory in that city, and the few observations he made were never reduced and published.

The observations discussed here form, I think, the most accurate determinations of declination ever made in this country; and when we consider the simplicity and elegance of the method, one can only wish to see it more generally applied.

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OBSERVATIONS OF THE *SATELLITE OF NEPTUNE*,

WITH THE 23-INCH EQUATORIAL, HALSTED OBSERVATORY, PRINCETON, NEW JERSEY.

[Communicated by Prof. C. A. YOUNG, Director.]

The observations are not corrected for differential refractions, but it was computed for several of the dates when it would have the greatest effect, and in all cases it is much less than 0″.01 on the distance measures. Observers Y = Young, McN = McNeill, H = Prof. Asaph Hall of Washington, who visited the Observatory on Nov. 19, 1883. In column "Eyes," *p* denotes that the eyes of the observer were parallel to the line between planet and satellite; *n* denotes that the eyes were normal to the above direction.

OPPOSITION OF 1883–84.

Date	Gr. M.T.	Posit. Ang.	No.	Eyes	Gr. M.T.	Distance	No.	Obs.	Power
	h m	° ′			h m	″			
1883 Oct. 10	14 59.2	196 33	3		15 8.7	11.63	4	Y	790
16	14 56.6	188 12	4		15 9.6	8.62	3	Y	
24	14 10.9	41 22	5		14 26.2	17.24	8	Y	460
Nov. 17	13 57.7	28 28	3		14 10.5	14.49	8	Y	460
19	14 57.1	233 21	5		15 12.6	15.99	6	Y	460
19	15 14.0	234 31	5		15 26.2	16.56	4	H	460

October 16. Satellite seen only by glimpses. Bright moonlight. Position readings, Y, 2; McN, 1; Baldwin, 1.

October 24. Satellite easily seen.

OPPOSITION OF 1884–85.

Date	Gr. M.T.	Posit. Ang.	No.	Eyes	Gr. M.T.	Distance	No.	Obs.	Power
	h m	° ′			h m	″			
1884 Nov. 22	14 8.5	326 10	4		14 25.9	6.50	2	Y	360
29	13 19.6	239 34	4		13 31.5	14.84	4	Y	360
Dec. 2	12 43.6	59 10	4		13 4.8	15.97	4	Y	360
3	13 7.3	28 41	4					Y	360
3	13 9.6	25 10	2					McN	360
4	15 17.1	289 4	4	*p*	15 25.0	8.57	4	Y	460
4	15 42.2	285 33	6	*p*	15 33.7	8.46	4	Y	360
5	13 26.6	235 10	8		13 47.5	16.79	6	McN	460&360
5					14 20.5	16.04	4	Y	360
16	14 8.3	274 12	2					Y	360
1885 Jan. 2	13 15.7	349 2	5					Y	
10	14 9.9	213 17	4		14 21.4	15.18	8	Y	460&360
13	14 42.3	32 55	6	*n*	14 49.2	14.81	8	Y	360

November 22. Very hard to see satellite; measures of distance rather uncertain.

November 29. Moonlight, very troublesome.

December 2. Moon full, troublesome, but satellite fairly seen.

December 3. Very bright moonlight and haze; too difficult to measure distance.

December 4. Seeing very steady and good.

December 5. Satellite seen only by occasional glimpses; trouble by fogging of eye-piece.

December 16. Very faint, seeing poor; distance about 7″, not measured.

January 10. Satellite hard to see.

OPPOSITION OF 1885–86.

Date	Gr. M.T.	Posit. Ang.	No.	Eyes	Gr. M.T.	Distance	No.	Obs.	Power
1885 Nov. 14	14 24.6 (h m)	51 40 (° ′)	5	*p*	14 48.2 (h m)	16.94 (″)	8	Y	360

Satellite easily seen.

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Opposition of 1886–87.

Date		Gr. M.T.	Posit. Ang.	No.	Eyes	Gr. M.T.	Distance	No.	Obs.	Power
		h m	° ′			h m	″			
1886	Nov. 26	13 24.4	23 13	10	*p*	13 25.6	12.32	8	Y	460
	27	14 18.2	278 15	1					Y	460
	29	13 6.0	198 22	5					Y	
	Dec. 8	14 9.8	1 36	5	*n*				Y	460
	9	15 27.3	258 48	6	*p*				Y	460
	10	13 9.2	225 37	5	*p*				Y	460
	14	13 15.0	352 20	6	*n*	13 19.5	7.67	2	Y	
	16	13 14.6	223 56	6	*p*	13 31.2	16.19	8	Y	460
	16	13 46.7	224 39	5					Y	460
	21	13 46.3	251 11	5	*p*	13 55.7	14.46	8	Y	460
	27	13 8.8	248 29	5	*p*	13 19.8	15.30	8	Y	460
1887	Jan. 21	14 9.8	186 0	1					Y	480
	25	14 2.0	258 32	5	*n*				Y	

November 27. Through thin clouds; clouded up after first measure.

November 29. Satellite very faint, too faint to measure distance.

December 8. Moon within 10°; visible only by glimpses; distance not attempted.

December 9. Moonlight; no illumination; satellite faint, but well seen.

December 10. Extremely difficult; not satisfactory; no use to measure distance.

Dec. 14. Through clouds; clouded up before completion of distance measures.

December 16. Seeing rather poor; positions unsatisfactory; satellite not seen steadily.

January 21. Very faint, through thin haze; seeing rather poor.

January 25. Through slight haze, very difficult; seen only by glimpses; distance estimated 5″ to 6″, too difficult to measure.

Opposition of 1887–88.

Date		Gr. M.T.	Posit. Ang.	No.	Eyes	Gr. M.T.	Distance	No.	Obs.	Power
		h m	° ′			h m	″			
1887	Oct. 15	15 25.0	25 48	5		15 31.7	13.44	5	Y	360
	Nov. 3	15 40.2	259 35	3	*p*				Y	460
	22	14 18.9	218 33	5	*n*	14 31.5	15.79	4	Y	460
	Dec. 6	14 21.1	59 2	6	*p*	14 29.2	16.23	4	Y	460
	6	15 22.5	58 22	6		15 28.4	17.00	4	Y	460
	13	15 18.3	10 58	6	*n*				Y	460
	13	15 32.3	15 17	6					McN	460
1888	Jan. 2	13 10.2	224 27	6	*p*	13 22.2	16.21	4	Y	460
	5	13 17.7	38 0	5	*n*	13 31.8	15.82	4	McN	360

November 3. Satellite visible with difficulty; haze became too thick for farther measures.

November 22. Weight very small; satellite very hard to see.

December 6. Seeing fair.

December 13. Seeing too bad to measure distance.

January 2. Seeing good.

January 5. Seeing rather poor, occasional cirrus clouds; satellite seen only by glimpses, and distance measures rather uncertain.

Princeton, New Jersey, 1888 *March* 12.

TWO HUNDRED SEVENTY-FOURTH ASTEROID.

A planet of the 13th magnitude was discovered by Palisa, at Vienna, on the third of April. The observation, transmitted telegraphically by Dr. Krueger, gives

1888 April 3^d.4211 Gr. M.T. 12^h 50^m 39^s.5 +0° 50′ 50″. Daily motion —48^s in α, and 5′ northward.

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PROPER MOTION OF THE STAR W.B. VI, 1500,

By LEWIS BOSS.

In comparing the positions of BESSEL's zones as corrected in LUTHER's tables (*Königs. Beobb.* Bd. XXXVII) with those resulting from the Albany A.G. zones, I have found very few errors of observation additional to those already pointed out by the labors of BESSEL, ARGELANDER, LUTHER and others. Usually, where such errors have been found, it is seen that the published material would not have sufficed for their detection. Ordinarily, some very simple supposition as to the source of error serves to reconcile BESSEL's with the modern observation. In the case of the star at $6^h 46^m 50^s.38$ in Zone 45, if we suppose that the "*Theile*" should read 1173 instead of "1273," as printed, the declination would have been 1° 25′ 39″.5, instead of 1° 26′ 13″.6, as BESSEL gives it. The former position reduced to 1875 would be 1° 20′ 28″.8, agreeing very satisfactorily with 1° 20′ 29″.6 as obtained from the Albany zones, in which the star is twice observed. Errors precisely similar to this have been found in the published zones of BESSEL; and such a mistake is one easy to make. To decide the case (at the same time with many others) I have recently reobserved this star, and the following table exhibits all the material of observation known to me. It is assumed that BESSEL requires no correction.

	Epoch of Obs.	α 1875.0	Δα	δ 1875.0	Δδ
		h m s	s	° ′ ″	″
Bes.(Z. 45)	1822.05	6 50 6.81	0.00	+1 21 2.9	—0.8
Alb.Zones	1880.16	6.58	+0.01	20 29.4	+1.0
Alb.Zones	1880.19	6.60	—0.01	29.9	+0.5
Alb.M.Obs.	1888.19	6.60	—0.04	27.3	—1.2
Alb.M.Obs.	1888.23	6.51	+0.05	26.2	—0.1

The columns Δα and Δδ are the residuals formed by supposing the proper motion to be $-0^s.004$ and $-0''.55$, respectively, and the position for 1875:

$$\alpha = 6^h\,50^m\,6^s.61 + 3^s.1028t - 0^s.0010\,\frac{t^2}{200}$$

$$\delta = +1^\circ\,20'\,33''.3 - 4''.350t - 0''.440\,\frac{t^2}{200}$$

Considering the Albany observations alone, the proper motion in declination would be much smaller (—0″.36); but of course very little weight attaches to a result depending on this small interval. The actual difference of the means of the Albany observations is more than five times the probable difference; and this fact makes the probability that the proper motion above deduced is real, very nearly absolute.

The star is of the eighth magnitude.

COMET 1888 *a* (*SAWERTHAL, Feb. 18*),

By WILLIAM C. WINLOCK.

The following elements have been computed from the Cape observation of February 18, the observation at the University of Virginia, March 13, and the Washington observation, March 30. The error in the apparent place reduction of March 13 has been corrected, and corrections for aberration and parallax have been applied:

$$T = 1888 \text{ March } 16.95952 \text{ Greenw. M.T.}$$

$$\left.\begin{aligned} \omega &= 359^\circ\ 49'\ 25'' \\ \Omega &= 245\ \ 30\ \ 14 \\ i &= \ \ 42\ \ 16\ \ 51 \end{aligned}\right\}\text{Mean eq. 1888.0}$$

$$\log q = 9.844502$$

U.S. Naval Observatory, April 11.

A comparison with the middle place, March 13, and with the Washington observation of March 18, gives the residuals:

(O—C)	Mar. 13.	Mar. 18.
$\delta\lambda \cdot \cos\beta$	—58″.4	—52″.2
$\delta\beta$	— 3 .8	— 3 .5

It will be remarked that the axis of the orbit lies close to the ecliptic, a fact which of itself seems to afford a slight suspicion of ellipticity.

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AN EXAMINATION OF SOME ERRORS POSSIBLY AFFECTING MEASURES OF DISTANCE, MADE WITH THE PRISM-APPARATUS OF M. LOEWY,

By GEORGE C. COMSTOCK.

If a pencil of rays from a star fall upon the objective of a telescope whose eye-piece is slightly out of focus, the pencil emergent from the eye-piece will enter the eye of an observer as a cone of circular cross-section and small vertical angle. The resultant visual effect is that of a star whose direction from the observer depends upon the mean direction of the rays which enter the eye, and considerations of symmetry show that this mean direction coincides with the axis of the cone. Since a change in the focusing of the eye-piece alters the angle of the cone, but does not sensibly affect the position of its axis, it follows that a small change in the focusing does not produce any systematic effect upon the apparent direction of the star, or upon a measured distance into which this direction enters. If, however, the incident pencil falls only upon a part of the objective which is not symmetrically distributed about its center, *e.g.*, upon one-half of the objective, the mean direction of the emergent rays will no longer coincide with the axis of the cone unless the eye-piece is perfectly focused, in which case the emergent rays are all parallel to the axis.

In the prism apparatus to be considered, rays coming from two stars are reflected from opposite faces of a prism placed symmetrically in front of the objective. These reflected rays pass through different parts of the objective, and their directions upon entering the eye depend upon the focusing of the telescope. The distance between the images of the stars, which is the quantity to be measured, will therefore also depend upon the focusing, and serious errors may thus be introduced into the results derived from such measures. It is the purpose of the present paper to consider these errors, and such others as arise from the use of only a part of the objective for each star, omitting all constant errors, since these will be eliminated in the end, as the observations contemplated with the prism apparatus are purely differential in their character.

The principle which furnishes the basis of the following investigation is due to Gauss, *Dioptrische Untersuchungen*, whose methods and notation I shall adopt. If we suppose any series of refracting media bounded by spherical surfaces whose centers lie in the same straight line, and suppose further a ray of light, making a small angle with this line and incident upon the first surface, to have for its equations

$$y = \frac{\zeta}{n^0}(x - E^0) + b\,; \qquad z = \frac{\gamma}{n^0}(x - E^0) + c \qquad (1)$$

then the ray of light emergent from the last surface will have as its equations

$$y = \frac{\zeta + kb}{n^*}(x - E^*) + b\,; \qquad z = \frac{\gamma + kc}{n^*}(x - E^*) + c. \qquad (2)$$

The rays are here referred to a system of coordinates, in which the line of centers of the bounding surfaces is the axis of x, the origin and the directions of the axes of y and z being left indeterminate. E^0 and E^* denote the principal points (*Hauptpunkte*) of the system of surfaces, n^0 and n^* the refractive indices of the first and last media, and k a constant, whose value depends upon the thicknesses and refractive indices of the intervening media and the curvatures of their surfaces. For the particular case of an achromatic objective or eye-piece, $n^0 = n^* = 1$ and $k = -\frac{1}{f}$, the negative reciprocal of the focal length of the compound lens.

The effect of the prism upon the course of a ray incident upon it having been elsewhere discussed, I shall confine my attention to the course of the ray between the prism and the retina of the eye, and shall consider the objective as a single lens, fully defined by its principal points E'_1, E'_2, and its focal length f'; the eye-piece as another lens, similarly defined by E''_1, E''_2 and f''; and those parts of the eye anterior to the retina as a third lens defined by E'''_1, E'''_2 and f'''. The several principal points are all supposed situated upon the axis of x. It appears from equations (1) and (2) that the relations existing between the z and x coordinates of any point in the path of a ray are of the same form as those between y and x; it will therefore be sufficient to make the analysis for the plane xy only, the corresponding relations in the plane xz

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being obtained, if desired, by substituting γ, c and z in place of ζ, b and y, in the resulting equations.

Let the equation of a ray incident upon any part of the objective be

$$(3)\qquad y = \zeta\,(x - E'_1) + b.$$

The equation of this ray after it has traversed the objective is found by applying equation (2) to be

$$(4)\qquad y = \left\{ \zeta - \frac{b}{f'} \right\} (x - E'_2) + b$$

Let the distance from E'_2 to E''_1 be $f' + f'' + q$, in which q is obviously the error of focusing, positive when the eye-piece is drawn out. We then have

$$E'_2 = E''_1 - (f' + f'' + q)$$

This value of E'_2 substituted in equation (4) gives

$$(5)\qquad y = \left\{ \zeta - \frac{b}{f'} \right\} (x - E''_1) + (f' + f'' + q)\,\zeta - \frac{f'' + q}{f'}\,b$$

which is the equation of the ray incident upon the eye-piece. Applying (2) to this expression, the equation of the ray emergent from the eye-piece is found to be

$$(6)\qquad y = \left\{ \frac{bq}{f'f''} - \frac{f' + q}{f''}\,\zeta \right\} (x - E''_2) + (f' + f'' + q)\zeta - \frac{f'' + q}{f'}\,b$$

This may be written

$$(7)\qquad y = \lambda\,(x - E''_2) + L$$

the quantities λ and L being abbreviations for the more complicated expressions of equation (6). Let r denote the distance from E''_2 to E'''_1, and eliminate E''_2 from (7). The resulting equation

$$(8)\qquad y = \lambda\,(x - E'''_1) + \lambda r + L$$

represents the path of the ray incident upon the eye of the observer. Again applying equation (2), the path of the ray emergent from the crystalline lens is found to be

$$(9)\qquad y = \frac{1}{n} \left\{ \lambda + k\,(\lambda r + L) \right\} (x - E'''_2) + \lambda r + L$$

in which n denotes the refractive index of the vitreous humor. If we identify the retina with its tangent plane at the point where the axis of x intersects the retina, call the abscissa of this point R, and put

$$R - E'''_2 = s$$

we shall find as the equation of the ray incident upon the retina

$$(10)\qquad y = \frac{1}{n} \left\{ \lambda + k(\lambda r + L) \right\} (x - R) + \lambda r + L + \frac{s}{n} \left\{ \lambda + k\,(\lambda r + L) \right\}$$

The point of intersection of this ray with the retina can, of course, be found by putting $x = R$.

We have, now, to trace in a similar manner, the course of a ray coming from a micrometer thread placed near the focus of the eye-piece. Let the coordinates of a point on this thread be

$$x = E''_1 - (f'' + p)\,; \qquad y = m\,; \qquad z = n$$

p denoting the error of focusing the eye-piece upon the thread. The equation of a ray proceeding from this point to the eye-piece will be of the form

$$y = \alpha\,(x - E''_1) + \beta$$

in which the value of α may be determined from the condition that the ray shall pass through the point above defined. The equation is thus transformed into

$$y = \frac{\beta - m}{f'' + p}\,(x - E''_1) + \beta \qquad (11)$$

and by (2) the equation of the ray emerging from the eye-piece is

$$y = -\,\frac{f''m + p\beta}{f''(f'' + p)}\,(x - E''_2) + \beta \qquad (12)$$

or

$$y = \mu\,(x - E''_2) + M. \qquad (13)$$

The course of this ray through the eye to the retina may be traced as above, and the equation of the ray incident upon the retina will be found to be

$$y = \frac{1}{n} \left\{ \mu + k\,(\mu r + M) \right\} (x - R) + \mu r + M + \frac{s}{n} \left\{ \mu + k\,(\mu r + M) \right\} \qquad (14)$$

In order that the star shall be seen bisected by the micrometer-thread, the values of y, given by equations (10) and (13) when $x = R$, must be equal, hence we may write as the condition for apparent coincidence of the thread and star

$$(\lambda - \mu)r + L - M + \frac{s}{n} \left\{ \lambda - \mu + k\,[(\lambda - \mu)r + L - M] \right\} = 0$$

which is equivalent to

$$(15)\qquad (\lambda - \mu) \left\{ \frac{s}{n} + r\left(1 + \frac{ks}{n}\right) \right\} + (L - M) \left\{ 1 + \frac{ks}{n} \right\} = 0$$

The quantities s and k depend upon the focal adjustment (accommodation) of the eye itself, and r depends upon the distance of the eye from the telescope. These quantities are all variable, and r is evidently independent of k and s, hence if (15) is to be satisfied for all adjustments and positions of the eye, each term must be separately equal to zero. If either term differs from zero, the coincidence of star and thread may be established or destroyed by a slight motion of the observer's head, or by a change in the accommodation of the eye, the micrometer-thread remaining constantly at a fixed setting. If we apply equation (2) to a pencil of parallel rays transmitted through the eye, we shall have $n^* = n$, and $E^* = E'''_2$, and the equation may be written

$$y = \frac{x - E'''_2}{n}\,\zeta + \left\{ 1 + \frac{k(x - E'''_2)}{n} \right\} b$$

In order that these rays shall be brought to a focus upon the retina, a condition which must be very approximately satisfied for distinct vision, the coefficient of b must be zero, and $x - E'''_2 = s$. Under these conditions, therefore,

$$1 + \frac{ks}{n} = 0$$

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and the second term of (15) vanishes. If this condition is satisfied, it is impossible that $\frac{s}{n}+r\left(1+\frac{ks}{n}\right)$ should also be zero, hence we have, as the remaining condition, $\lambda-\mu=0$.

We may pass to the more general case, in which the incident rays are not parallel, and are not brought to a sharp focus upon the retina, by writing $1+\frac{k(s+h)}{n}=0$, in which h denotes the distance of the focus from the retina. We shall then have $1+\frac{ks}{n}=-\frac{kh}{n}=\frac{h}{s}$ approximately.

In place of $\lambda-\mu=0$ we must now write

$$\lambda-\mu=\frac{h}{s\left\{\frac{s}{n}+r\left(1+\frac{ks}{n}\right)\right\}}(L-M)=\frac{hn}{s^2+rhn}\quad(L-M)$$

If we now substitute for λ, μ, L, and M their values, and neglect terms of the order h^2, we shall find

$$\frac{f'+q}{f''}\zeta-\frac{bq}{f'f''}-\frac{f''m+p\beta}{f''(f''+p)}=-\frac{hn}{s^2}\left\{(f'+f''+q)\zeta-\frac{f''+q}{f'}b-\beta\right\}$$

which may be written

$$\zeta=\frac{f''m+p\beta}{(f'+q)(f''+p)}-\frac{hnf''(f'+f''+q)}{s^2(f'+q)}\zeta+\frac{hnf''\beta}{s^2(f'+q)}+\frac{bq}{f'(f'+q)}+\frac{hnf''(f''+q)}{s^2f'(f'+q)}b. \tag{16}$$

To interpret this equation we note that the quantities b and β, which appear in it, were introduced as the absolute terms of the equations of rays of light from a star, and from a micrometer-thread, respectively. The total visual effect produced at the retina is due to a large number of rays from each source, and as all the rays coming from a common source have equations of like form, and differ only in the particular values of b and β belonging to the several rays, we may define the b and β which appear in equation (16) as mean values for the systems of rays to which they respectively belong. The equation will then represent the resultant of these rays. Let us now suppose that the incident rays from the star fall upon the whole objective, that the telescope is perfectly focused, and that the rays transmitted through the eye are brought to a focus upon the retina; *i.e.*, let us put

$$b=0\quad,\quad p=0\quad,\quad q=0\quad,\quad h=0.$$

Equation (16) then becomes

$$\zeta=\frac{m}{f'}$$

a relation which can be readily verified from the geometrical relations of the quantities involved, ζ being the tangent of the angle which the incident ray makes with the axis of the objective, and m the distance, from that axis, of a micrometer-thread seen superposed upon the star. In the method of observing with which we are now concerned, a silvered glass prism is placed symmetrically in front of the objective of a telescope, and rays of light coming from a star are reflected from it through a part of the objective only. The effect of this unsymmetrical disposition of the incident rays is to make b a quantity sensibly different from zero, while the other quantities, p, q and h, remain unaffected by the introduction of the prism. Those terms of (16) which contain b as a factor represent errors possibly present in the case of prism-observations, but which become zero when the rays of light fall symmetrically about the center of the objective. They, therefore, distinguish these observations from those made in the ordinary manner, and as it is my purpose in the present paper to investigate only those errors which are peculiar to the prism-observations, I shall neglect those terms of (16) which represent errors common to both kinds of observing, and write in a simplified form the equations for two stars whose images are formed by rays reflected from opposite faces of the prism. Thus

$$\zeta_1=\frac{m_1}{f'}+\frac{qb_1}{f'(f'+q)}+\frac{hn}{s^2}\left(\frac{f''}{f'}\right)^2b_1 \tag{17}$$
$$\zeta_2=\frac{m_2}{f'}+\frac{qb_2}{f'(f'+q)}+\frac{hn}{s^2}\left(\frac{f''}{f'}\right)^2b_2$$

In the use of the prism-apparatus the telescope is to be directed to the middle point of the arc joining the two stars to be observed, and since the direction of the axes of y and z was left undeterminate, we may now assume that the plane of xy passes through the two stars. We have then, for the angular distance between the two images in the field of view of the telescope,

$$\Delta=\zeta_1-\zeta_2=\frac{m_1-m_2}{f'}+\frac{b_1-b_2}{f'(f'+q)}q+\frac{b_1-b_2}{(s\upsilon)^2}hn. \tag{18}$$

The quantity

$$\upsilon=\frac{f'}{f''}$$

is the magnifying power employed. The term containing q represents the effect upon the measured distance of bad focusing of the eye-piece upon the star; the term in h the corresponding effect arising from mal-accommodation of the eye. These terms are expressed as abstract numbers, and must be multiplied by 206265 to turn them into seconds of arc.

To compare equation (18) with observation, I have resorted to the following experiment. A pasteboard cap, with two circular apertures symmetrically placed with respect to its center, was fitted over the objective of the 15½-inch equatorial of the Washburn Observatory. The telescope being pointed upon a star, a pencil of rays from this star passes through each aperture, and forms an image of the star at the principal focus of the objective. If the eye-piece is properly focused, an observer will see in the telescope a single star, but if the eye-piece be displaced from the true focus by a quantity q, the star will separate into two whose

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distance apart will depend upon q. Applying equation (18) to this case, and noting that $\zeta_1 - \zeta_2 = 0$, we have

$$(19) \qquad \frac{m_2 - m_1}{f'} = d = \frac{b_1 - b_2}{f'^2}\, q + \frac{b_1 - b_2}{(s\upsilon)^2}\, hn$$

in which d denotes the measured distance between the images. After trying apertures of different diameters, from an eighth of an inch up to two and a half inches, I adopted the latter size as giving the best definition. With this aperture a star of the second magnitude presents two round, well defined disks of 3″ diameter, with rather woolly edges, which, however, admit of precise measurement when they are placed anywhere from 3″ to 20″ apart. In the apparatus employed, the distance between the centers of the apertures, $b_1 - b_2$, was 12.56 inches, the focal length, f', 245 inches, and the magnifying power, υ, 304 diameters. The sliding tube, which forms the eye-end of the telescope, has engraved upon it a scale of twentieths of an inch. By turning a focusing screw the eye-end may be moved in, so that the divisions of this scale successively disappear within the telescope-tube. The position of the eye-end is determined by noting that part of scale which is just disappearing within the tube. This part, always an exact division, is called the scale-reading, and is used for determining q by a method given below. The cap was placed over the objective so that the line joining the centers of the apertures was made approximately parallel to a declination circle, the eye-end set to a given scale-reading, and three double distances of the images measured. The mean result of these three measures is called a single distance. The eye-end was then set at another scale-reading, and the distance again measured, etc. A number of such settings, observed consecutively, constitute a series. The following observations made on March 28, 29, 30 and 31, 1888, are the first six series thus taken. The atmospheric conditions ranged from "good" to "poor." Series II, III, and IV, were observed through clouds which seriously interfered with the observing, changing the images from bright disks to very faint points of light, and at times entirely obscuring them.

Series I. *α Hydrae.* Observer C. Assumed Focus 26.00.

Scale-Reading	20	21	22	23	24	28	29	30	31
Measured Distance	12.63″	10.69″	8.56″	6.46″	4.35″	4.42″	6.41″	8.45″	10.60″
Computed Distance	12.93	10.77	8.62	6.47	4.31	4.31	6.47	8.62	10.77
C—O	+0.30	+0.08	+0.06	+0.01	—0.04	—0.11	+0.06	+0.17	+0.17

Series II. *α Hydrae.* Observer E. Assumed Focus 25.48.

Scale-Reading	20	21	22	23	24	27	
Measured Distance	11.63″	9.45″	7.61″	5.54″	3.23″	3.30″	Stopped by clouds
Computed Distance	11.81	9.66	7.50	5.35	3.19	3.28	
C—O	+0.18	+0.21	—0.11	—0.19	—0.04	—0.02	

Series III. *α Urs. Maj.* Observer C. Assumed Focus 25.50

Scale-Reading	19	20	21	22	30	31	32	
Measured Distance	13.56″	11.72″	9.47″	7.61″	9.57″	11.63″	13.77″	Through clouds
Computed Distance	14.02	11.86	9.68	7.55	9.70	11.86	14.02	Difficult
C—O	+0.46	+0.14	+0.21	—0.06	+0.13	+0.23	+0.25	

Series IV. *Polaris.* Observer E. Assumed Focus 25.39.

Scale-Reading	21	22	23	27	28	29	30	
Measured Distance	8.89″	7.11″	5.28″	3.35″	5.47″	7.57″	9.89″	Through clouds
Computed Distance	9.46	7.31	5.15	3.48	5.63	7.78	9.95	Very difficult
C—O	+0.57	+0.20	—0.13	+0.13	+0.16	+0.21	+0.06	

Series V. *Polaris.* Observer C. Assumed Focus 25.37.

Scale-Reading	20	21	22	23	24	27	28	29	30	31
Measured Distance	11.46″	9.29″	7.39″	4.99″	3.30″	3.67″	5.68″	7.88″	9.96″	11.98″
Computed Distance	11.58	9.42	7.27	5.10	2.95	3.52	5.67	7.83	9.98	12.14
C—O	+0.12	+0.13	—0.12	+0.11	—0.35	—0.15	—0.01	—0.05	+0.02	+0.16

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Series VI. *Procyon.* Observer C. Assumed Focus 25.46.

Scale-Reading	20	21	22	23	24	27	28	29	30	31
	"	"	"	"	"	"	"	"	"	"
Measured Distance	11.79	9.56	7.40	5.31	3.14	3.39	5.38	7.70	9.90	11.77
Computed Distance	11.78	9.62	7.46	5.30	3.15	3.32	5.48	7.63	9.79	11.95
C—O	—0.01	+0.06	+0.06	—0.01	+0.01	—0.07	+0.10	—0.07	—0.11	+0.18

The computed distances, which are here compared with the measured ones, are the values of the second number of (19) when h is put equal to zero. To obtain the value of q required for this computation, the scale-reading when the eye-piece is exactly focused must be known. If this reading be called c, and a and b represent scale-readings on opposite sides of the focus, $a > c > b$, and A and B the corresponding measured distances of the images, we have the relation

$$\frac{a-c}{c-b} = \frac{A}{B}$$

which is readily transformed into

$$c = \tfrac{1}{2}(a+b)-\tfrac{1}{2}(a-b)\,\frac{A-B}{A+B} \tag{20}$$

and for any observation made at the scale-reading, x

$$q = c-x$$

From each pair of measures made at approximately equal distances on opposite sides the focus, a value of c is derived, and the mean of these values for a series is the assumed focus for that series.

The legitimacy of the assumption $h=0$ may be tested in the following manner. Each measured double distance of two bodies furnishes a determination of the coincidence of the fixed and movable micrometer threads, which is independent of q, and also of h, if h is constant. If h is variable, it will produce errors in the determination of the coincidence, and thereby increase the probable error of a single determination. From the 49 measures contained in the six series here given, I find for the probable error of a single determination of coincidence, assuming a constant value of the coincidence, $r = \pm 0''.094$. From 133 measures of double stars with the same instrument, by observer C, the probable error of a coincidence is $r = \pm 0''.098$. The probable error of a distance is the same as the probable error of a coincidence; and it appears from the preceding comparison that the term in h does not sensibly increase the accidental error of a single measurement. We may obtain a similar conclusion from the residuals, C—O. These residuals contain the combined effects of

(*a*) Accidental error in measuring the distance of the images

(*b*) Errors in setting the eye-end to correspond to the scale-reading

(*c*) Errors in the graduation of the scale

(*d*) The observer's systematic error

(*e*) The error arising from the term in h

(*f*) Errors in the quantities b_1-b_2 and f', used in obtaining the computed distance.

If we treat the values of C—O as residuals, and derive from them the probable error of a single observation, we shall find $r = \pm 0''.112$. Deducting from this the known effect of the accidental error of a single measure derived from the double-star work, there remains $\pm 0''.054$ arising from the remaining five sources of error. When it is considered that an error of 0.001 inch in (*b*) or (*c*), about the *minimum visibile* of the naked eye, produces an error of $0''.043$ in the distance, and that the systematic errors depending on the distance may be considerable quantities, the conclusion appears justified that those errors of observation with the prism-apparatus, both accidental and systematic, which arise from defective or varying accommodations of the eye, are quantities considerably less than the accidental errors of double-star work conducted in the customary manner. We may, therefore, drop from consideration the last term of equation (19), and write

$$d = \frac{m_1-m_2}{f'} + \frac{b_1-b_2}{f'^2}\,q.$$

The observations just discussed show that the term in q cannot be neglected. With the apparatus above described, errors of $1''$ may easily arise from this source, unless unusual precautions are taken in focusing the telescope. By the method above described for determining c the eye-piece may readily be focused within one or two thousandths of an inch, as I have found from repeated experience, and the resulting error thus reduced to a comparatively small quantity. Even this error may be eliminated in a determination of the constant of aberration, by combining observations of pairs of stars situated in opposite parts of the heavens; the observations being made in the same position of the eye-piece. The epoch of maximum distance of one of these pairs coincides with that of minimum distance of the other, and any error due to instrumental sources will appear with opposite signs in the results derived from the two pairs, and will hence be eliminated from the mean.

The very considerable measure of precision attained in the observations with the perforated cap suggests another application of it which seems worthy of attention. The motion of the eye-piece furnishes a means whereby an artificial double star may be produced, whose components shall be separated by any required distance, and this distance may be accurately determined by measuring the displacement of the eye-piece. So, also, the position-angle of the components may be varied at will, by rotating the cap about the line of sight. The comparison of a series of measured distances and position-angles of the artificial double star with computed values may be of service in determining the observer's systematic error in measures of this kind. Whether such application can profitably be made remains a subject for further research.

Washburn Observatory, 1888 *April* 10.

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ELLIPTIC ELEMENTS OF COMET 1888 a,

By LEWIS BOSS.

Some of the observations used in the calculations of this article have not hitherto been published, and the corrected epochs and positions of all of them are accordingly given in the following table.

	Gr. M.T.	α 1888.0	δ 1888.0
		° ′ ″	° ′ ″
Cape	Feb. 18.6007	287 53 8.7	—56 3 50.7
Albany	March 17.9255	319 9 15.7	—14 46 49.5
Albany	March 24.9233	324 47 16.1	— 5 16 59.8
Albany	March 30.9072	329 28 38.1	+ 1 55 15.9
Albany	April 6.8989	334 47 18.7	+ 9 12 57.9
Wash'n.	April 11.8729	338 25 45.5	+13 43 10.2
Albany	April 18.8547	343 18 27.7	+19 12 7.3
Albany*	April 28.8691	349 47 11.2	+25 39 56.2

Since several computers have already shown that it is impossible to harmonize the Cape observation with those made since perihelion, on the supposition of a parabolic orbit, it will first be necessary to find whether the later observations alone are consistent with a parabola. For this purpose the calculation is based on the second, fourth and seventh of the observations in the above list. The observation of April 18, while unexceptionable as to the equatorial comparison, depends upon the star DM. +19° 5048; and the position is known only from two LALANDE observations, combined with an equatorial comparison with a star in BESSEL's zone 201. The three results for position agree very well, however. The following parabolic elements result:

$$\begin{aligned} T &= 1888 \text{ March } 17.0137 \text{ Gr. M.T.} \\ \left.\begin{aligned} \omega &= 359°\ 57'\ 5''.5 \\ \Omega &= 245\ \ 26\ \ 52\ .8 \\ i &= 42\ \ 15\ \ 1\ .0 \end{aligned}\right\} & 1888.0 \\ \log q &= 9.844524 \end{aligned}$$

This represents the observations of March 17 and April 18, and compares with the three observations designated below — in the sense (C—O) — as follows:

	$\Delta\lambda$	$\Delta\beta$
	″	″
Cape, Feb. 18	—269.9	+29.5
Albany, March 30	+ 19.5	— 5.8
Albany, April 6	+ 18.5	— 1.7

Any attempt to diminish either of the residuals for March 30 will increase the other in a rapid ratio, the parabola being essentially normal for the three observations used in calculating the elements.

These discrepancies are clearly intolerable, even for the observations since perihelion; and it is extremely improbable that any such error as is indicated in the Cape observation was actually committed, either in observation or telegraphic transmission. It therefore becomes of interest to test the question of ellipticity. The first, second and seventh of the observations at the head of this article lead to the following elliptic elements:

$$\begin{aligned} T &= 1888 \text{ March } 16.9987 \\ \left.\begin{aligned} \omega &= 359°\ 54'\ 58''.4 \\ \Omega &= 245\ \ 22\ \ 46\ .6 \\ i &= 42\ \ 15\ \ 23\ .1 \end{aligned}\right\} & 1888.0 \\ \log e &= 9.997790 \\ \log q &= 9.844329 \end{aligned}$$

This, of course, represents the three observations used, but cannot be regarded as decisive, unless it represents observations not used in the calculation, within a reasonable amount of error. Following is the result of comparison (C—O):

	$\Delta\alpha$	$\Delta\delta$		$\Delta\alpha$	$\Delta\delta$
	″	″		″	″
Feb. 18	0.0	0.0	April 6	—6.7	—2.6
March 17	+0.3	—1.3	April 11	—5.8	—0.1
March 24	—1.2	—4.3	April 18	0.0	0.0
March 30	—8.5	—7.2	April 28	+4.6	+6 6

Taken in connection with the discrepancies for parabolic elements, these residual differences indicate that, while the eccentricity is probably somewhat larger than that above found, it really exists. They are probably in large part due to comparatively small errors in the observations of Feb. 18 and April 18. The above eccentricity corresponds to a period of 1615 years. I suspect that the true period will be decidedly greater than 2000 years.

Following are the heliocentric equations:

$$\begin{aligned} x &= r\ [9.898389]\ \sin(v + 328°\ 9'\ 7''.6) \\ y &= r\ [9.999694]\ \sin(v + 236\ 29\ 13.9) \\ z &= r\ [9.787085]\ \sin(v + 323\ 42\ 17.9) \end{aligned}$$

and by the aid of these has been computed the following

EPHEMERIS FOR GREENWICH MIDNIGHT.

1888	App. α	App. δ	log r	log Δ
	h m s	° ′ ″		
May 2.5	23 27 55.8	+27 41 4	0.05786	0.19744
3.5	23 30 17.2	28 12 49		
4.5	23 32 37.0	28 43 56	0.06851	0.20435
5.5	23 34 55.4	29 14 26		
6.5	23 37 12.1	29 44 20	0.07897	0.21102
7.5	23 39 27.4	30 13 40		
8.5	23 41 41.0	30 42 27	0.08923	0.21746
9.5	23 43 53.1	31 10 41		
10.5	23 46 3.7	31 38 23	0.09928	0.22369
11.5	23 48 12.7	32 5 35		
12.5	23 50 20.1	32 32 17	0.10914	0.22969
13.5	23 52 25.9	32 58 30		
14.5	23 54 30.2	33 24 15	0.11880	0.23548
15.5	23 56 32.9	+33 49 34		

* Depends on WEISSE 377. BESSEL-LAL. = +0s.45, —12″.6.

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1888	App. α	App. δ	log r	log Δ	1888	App. α	App. δ	log r	log Δ
	h m s	° ′ ″				h m s	° ′ ″		
May 16.5	23 58 34.1	+34 14 26	0.12826	0.24106	June 1.5	0 27 19.0	+40 2 24	0.19730	0.27864
17.5	0 0 33.7	34 38 52			2.5	0 28 53.4	40 21 32		
18.5	0 2 31.7	35 2 54	0.13753	0.24643	3.5	0 30 26.1	40 40 25	0.20516	0.28252
19.5	0 4 28.1	35 26 32			4.5	0 31 57.2	40 59 3		
20.5	0 6 23.0	35 49 47	0.14661	0.25160	5.5	0 33 26.6	41 17 26	0.21287	6.28623
21.5	0 8 16.3	36 12 39			6.5	0 34 54.4	41 35 35		
22.5	0 10 8.1	36 35 9	0.15550	0.25658	7.5	0 36 20.5	41 53 30	0.22042	0.28978
23.5	0 11 58.3	36 57 19			8.5	0 37 44.9	42 11 11		
24.5	0 13 46.9	37 19 7	0.16421	0.26136	9.5	0 39 7.6	42 28 39	0.22783	0.29317
25.5	0 15 33.9	37 40 36			10.5	0 40 28.6	42 45 54		
26.5	0 17 19.4	38 1 45	0 17274	0.26595	11.5	0 41 47.8	43 2 56	0.23509	0.29639
27.5	0 19 3.3	38 22 35			12.5	0 43 5.3	43 19 46		
28.5	0 20 45.6	38 43 8	0.18109	0.27036	13.5	0 44 21.1	43 36 23	0.24222	0.29947
29.5	0 22 26.4	39 3 22			14.5	0 45 35.1	43 52 48		
30.5	0 24 5.5	33 23 19	0.18928	0.27459	15.5	0 46 47.5	+44 9 1	0.24921	0.30240
31.5	0 25 43.1	+39 43 0							

The light-ratio to that of discovery is on May 2, 0.195, and on June 15, 0.050.

Albany, 1888 *April* 29.

OBSERVATIONS OF COMET 1888 *a* (SAWERTHAL),

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6 INCH EQUATORIAL,

BY PROF. E. FRISBY AND W. C. WINLOCK.

1888 Washington M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
h m s			m s	′ ″	h m s	° ′ ″	s	″	
Apr. 11 15 59 30.	1	19 , 4	—1 35.46	—14 18.8	22 33 42.85	+13 43 3.0			
	2	17 , 4	—2 40.62	—12 33.2	22 33 43.58	+13 43 10.5	n9.664	0.709	F
	3	15 , 4	—5 12.79	+ 1 10.0	22 33 43.75	+13 43 9.5			
" 16 26 3.5	4	15 , 3	+0 26.15	— 2 58.9	22 33 45.60	+13 43 59.1	n9.651	0.684	F
16 16 4 52.	5	25 , 5	+0 26.75	+ 8 22.6	22 47 49.82	+17 44 24.9	n9.668	0.673	F
23 17 16 28.	6	29 , 6	—1 12.38	— 5 52.7	23 6 34.43	+22 37 48.4	n9.669	0.620	W

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	22 35 19.20	—0.89	+13 57 30.9	— 9.1	⅕(W.Bessel+Rümker+Lam.+2 Grant)
2	22 36 25.09	—0.89	+13 55 52.9	— 9.2	⅓(W.Bessel+Rümker+Lamont)
3	22 38 57.44	—0.90	+13 42 8.2	— 8.7	⅓(W.Bessel+2 Grant
4	22 33 20.34	—0.89	+13 47 7.1	— 9.1	Weisse's Bessel
5	22 47 23.86	—0.79	+17 36 12.0	— 9.7	Bonn Obs. VI, +17° 4822
6	23 7 47.55	—0.74	+22 43 51.7	—10.6	Bonn Obs. VI, +22° 4793

NEW ASTEROIDS.

A planet of the eleventh magnitude was discovered on the 15th of April, by PALISA, at Vienna, being the two hundred and seventy-fifth asteroid.

Another, the two hundred seventy-sixth, was also discovered by PALISA, April 17.

The observations, as transmitted telegraphically by Dr. KRUEGER, through the *Science Observer* Code, are as follows:

1888 April 15.5190 Greenw. M.T. $\alpha = 189° 46'$ $\delta = +3° 29'$ Daily motion, —40ˢ in α, and 0° 4′ northward

1888 April 17.5287 Greenw. M.T. $\alpha = 211° 11' 2''$ $\delta = -12° 34' 51''$ Daily Motion, —44ˢ in α, and 0° 11′ northward

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ON A NEW VARIABLE OF LONG PERIOD,

/ Kudne 3881

$10^h\ 44^m\ 34^s\ -20^\circ\ 28'.8$ (1855.0)

By S. C. CHANDLER, Jr.

Observations during the last month seem to establish beyond doubt the variability of this star, which was suspected to be variable by Dr. Gould, from the fact that, although it was estimated in 1871, at Cordoba, as $7^M.3$, it was invisible on three other occasions with the opera-glass. It was not included in the *Uranometria Argentina*.

On April 2 of the present year the star attracted my attention, being found, by careful comparison with its neighbors, to be only $9^M.0$ or $9^M.1$, while it was given as $6^M.7$ in the SDM. The star is of the most vivid red. I know of but two or three other variables, such as *V Cygni* and *S Cephei*, which exceed it in intensity of color. The variations during the past month have been very slight, and it manifestly belongs to the class of long-period variables. Indeed, a collation of all the known estimates of its magnitude seems to indicate that the period is over 500 days, and consequently among the longest known. These estimates are here given, for convenience in any future discussion of the period.

1797 Mar. 19	6.7 mag.	Lalande	Bien rouge
1851 Feb. 15	6 "	Argelander	Sehr roth
1871 July 6	7.3 mag.	Cordoba	
1873 April 20	7 "	Birmingham	
" June 9	Invisible in O.G.	Cordoba	
" Aug. 14	" "	"	
1874 Jan.	" "	"	
" May 8	8 mag.	Birmingham	Fine red
1876 Mar. 22	7.2 "	Copeland	Brown red
" April 1	7 "	Birmingham	
" April 30	7.5 "	"	Ruby
1877 May	8 "	Cordoba	
1879 Feb. 22	6.0 "	Copeland	Copper red
" Mar. 19	6.8 "	"	

There are besides four observations of it in the Cordoba General Catalogue, 8^M.

From these data, in connection with my own observations, I infer the hypothetical elements,

1873 March + 535 days,

which, however, rest on an exceedingly slender basis. Direct observations must be awaited to establish the period with any certainty. The Cordoba data seem to afford good evidence that the period is not less than a year.

Cambridge, 1888 *May* 3.

ELLIPTIC ELEMENTS OF COMET 1888 a,

By Rev. GEORGE M. SEARLE.

I have computed the following elliptic elements of Comet 1888 a, by the method given in No. 162 of this Journal, from the Cape observation of Feb. 18, the Albany observation of March 17, and one made at the observatory of Harvard College on April 16, by Mr. Wendell.

$$
\begin{aligned}
T &= 1888 \text{ March } 16.99894 \text{ Greenw. M.T.} \\
\Omega &= 245^\circ\ 23'\ 1''.5 \\
\omega &= 359\ \ 54\ \ 55\ .3 \\
i &= 42\ \ 15\ \ 24\ .0 \\
\log q &= 9.844330 \\
e &= 0.9949912
\end{aligned}
\quad \left.\right\} 1888.0
$$

from which we have $\log a = 2.1446$ (this was the assumption made for the last hypothesis), and the period equal to 1648 years.

The middle place is represented as follows, (O—C):

$$\Delta\lambda = -2''.9 \qquad \Delta\beta = +2''.6$$

It could easily be more accurately represented without much change in the elements; but it seems quite plain that unless the Cape observation is in error, it cannot be by any parabolic orbit, which will always give too small a radius vector for the middle place, and consequently a negative O—C in λ. It may be remarked that the position of the orbit is remarkably favorable for the manifestation of ellipticity, should it exist.

New York, 1888 *April* 28.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 172.

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OBSERVATIONS OF SUN-SPOTS,

By EDWIN F. SAWYER.

The following observations of sun-spots were made during the years 1872–3 and '74, using a $2\frac{1}{4}$-inch refractor by Bardou, and a magnifying power of about 60. In making the observations, direct vision was generally resorted to, although a diagonal eye-piece was occasionally employed, using a combination of green and red shade-glasses. With the exception of the months of February, March and April, 1873, when other duties permitted only occasional observations, and the months of November and December of the same year, when they were wholly discontinued, the sun's disc was scrutinized on every clear day.

The observations are given in tabular form, as the best suited for publication here, although the original work included careful drawings of the sun's surface on each day.

In publishing the observations at this late day, it is done in the hope that they may prove of some value in filling gaps in similar series by other observers.

The letters *a* and *p* denote *a.m.* and *p.m.* respectively.

Date.	Time.	Groups	Spots	Date.	Time.	Groups	Spots	Date.	Time.	Groups	Spots	Date.	Time.	Groups	Spots
1872	h m			1873	h m			1873	h m			1873	h m		
Dec. 2	3 30 *p*	4	25	Jan. 25	2 30 *p*	4	25	May 30	5 30 *p*	6	22	July 6	5 *p*	3	14
3	3 10	4	23	28	3 45	3	19	31	6	4	11	7	5	4	11
4	3	5	28	29	3 40	3	20	June 1	6 30	4	14	9	5	2	8
6	3	6	21	31	3 10	6	31	2	5 45	5	10	10	5	1	5
7	2 40	6	30	Feb. 2	2 40	5	17	4	5 30	4	12	12	6	2	5
10	3 10	5	12	4	2 50	5	18	5	4 30	3	9	13	5	2	10
11	3 15	5	27	5	2 45	5	20	6	4 30	3	8	14	4 30	2	6
13	2 45	5	14	6	2 40	4	10	8	5	3	8	15	5	1	2
14	2 15	6	13	8	3 50	4	11	9	5	2	5	16	4 30	2	6
15	2 45	7	15	Mar. 12	3 50	4	18	10	5 30	2	2	20	5	2	8
17	2 50	5	17	14	2 35	3	14	11	4 30	1	1	21	5	3	8
19	3 10	3	18	31	4 10	4	21	12	5	0	0	22	5	4	17
21	2 15	3	17	Apr. 1	3	5	22	13	4 30	0	0	23	4 30	4	18
22	3 10	4	10	4	3 25	4	15	15	4 30	0	0	24	5	5	16
24	4 10	2	2	23	3 30	3	8	16	4 30	0	0	25	5 30 *p*	5	23
25	3 30	2	3	30	3 15	4	15	17	4 30	0	0	26	8 *a*	5	23
27	4 5	3	5	May 4	3 15	3	9	18	4 30	1	1	28	4 *p*	6	25
28	2 15	5	18	5	3 45	3	8	19	4 30	1	2	29	4 *p*	7	21
30	3 40	5	33	6	3 30	3	9	20	4 30	1	3	30	7 *a*	7	18
1873 Jan. 1	3 10	4	33	12	4 45	2	6	21	6	1	3	31	8 *a*	7	11
4	2 10	5	24	13	5	2	4	22	5 30	1	3	Aug. 1	4 30 *p*	4	10
6	3 10	5	14	14	4	2	4	23	4 30	2	4	2	7 30 *a*	4	13
9	3 10	2	3	15	6	1	2	24	4 30	2	6	4	7	3	6
10	2 50	3	7	19	4 30	0	0	25	5	3	7	5	7	4	10
11	2	3	4	20	4 30	0	0	27	5	3	6	6	7 30	3	10
12	2	4	8	24	6 30	3	8	29	5	5	13	7	7	4	12
14	3 50	5	14	26	5 30	3	15	30	4 30	4	16	8	7 30	3	5
16	3 45	2	14	27	5	3	15	July 2	5	5	19	9	7 15 *a*	3	6
22	2 45	2	3	28	5 30	4	13	4	5 10	3	15	10	4 *p*	2	5
23	2 45 *p*	3	6	29	5 30 *p*	4	18	5	6 *p*	3	21	12	4 *p*	2	4

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Date.	Time.	Groups	Spots	Date.	Time.	Groups	Spots	Date.	Time.	Groups	Spots	Date.	Time.	Groups	Spots
1873	h m			1873	h m			1874	h m			1874	h m		
Aug. 17	4 p	2	6	Oct. 17	8 a	4	7	Mar. 1	2 p	3	9	May 10	4 p	4	14
24	4 30	2	27	21	8	1	1	2	8 a	2	8	11	5	4	22
25	4	2	27	22	8	1	1	5	8	2	12	12	7 a	2	22
26	4	2	27	23	8	2	3	6	8	2	10	13	7 30	2	17
27	4 p	2	24	26	2 30 p	4	14	8	2 30 p	2	6	14	7	2	12
28	7 a	3	29	29	4	3	5	9	8 a	2	2	15	7	2	9
29	3 p	3	45	30	8 a	2	2	11	8	2	3	17	4 30 p	2	4
30	3	3	41	1874 Jan. 4	12 45 p	3	4	13	4 p	2	10	18	7 a	2	3
Sept. 3	3	2	10	9	3 30	3	15	14	8 a	2	12	19	6 45	2	7
5	3	5	13	10	3 30	3	14	15	3 p	2	6	20	7	3	14
6	3	3	12	11	11 a	2	6	20	4	3	6	22	5 45 p	1	8
8	3	1	4	12	3 30 p	1	7	21	7 30 a	2	7	23	7 a	1	9
9	3	1	6	13	8 a	1	6	22	2 30	1	5	24	5 45 p	3	3
11	3	1	3	15	8	3	11	23	8 a	1	2	26	6 45 a	2	3
12	3	2	3	16	3 30 p	2	8	24	8	2	2	27	5 p	1	4
13	3	3	5	17	8 a	4	9	25	8	3	9	28	6 30 a	1	4
15	4	3	6	18	12 15 p	2	12	27	3 p	3	9	29	7	2	20
16	4 p	3	10	20	8 a	1	6	28	3	2	5	30	8	1	9
17	7 a	3	9	23	3 30 p	2	6	30	8 a	2	3	31	5 p	4	12
18	7 a	2	9	24	8 a	3	9	Apr. 2	4 p	4	13	June 2	6 45 a	2	4
21	3 p	2	5	25	12 15 p	4	13	5	4	3	5	3	7	2	3
22	3	4	12	26	8 a	4	12	6	8 a	3	5	5	5 30 p	2	2
24	3 30 p	3	11	29	8	2	23	11	7 30	4	9	8	6 30 a	2	6
25	7 15 a	4	12	30	4 p	4	13	12	3 45 p	2	6	9	6 45	3	9
26	7 15	4	13	Feb. 1	1	5	7	13	7 30 a	3	9	10	7 15	2	9
27	7 15	4	10	4	3 30	4	9	14	7	3	5	13	7	2	11
28	noon	2	7	5	4	4	9	15	7	2	7	14	5 15 p	5	18
29	7 15 a	3	12	7	3 30 p	3	11	16	7 15	2	5	15	6 45 a	3	14
30	4 p	2	14	8	12	1	5	18	7 30	1	2	18	4 p	2	47
Oct. 1	7 30 a	3	12	9	8 a	1	5	19	3 p	1	3	21	4 45	2	35
2	7 30 a	4	13	11	8	2	7	22	7 30 a	0	0	23	7 a	3	28
3	3 30 p	4	15	12	8	2	7	24	4 p	0	0	24	7	2	15
5	3 p	3	7	14	3 30 p	3	10	27	8 a	1	1	25	5 p	3	8
9	7 30 a	3	8	15	1	3	7	28	7 30	1	1	27	6 25	4	26
10	7 30	3	6	17	3 15	4	9	30	5 40 p	3	5	28	5 30	4	48
11	7 30 a	3	6	18	8 a	3	3	May 1	5	3	5	29	7 15 a	4	44
12	1 30 p	2	4	19	8	3	3	3	4 30	3	17	30	7	4	53
13	7 30 a	2	5	20	3 30 p	3	8	4	7 15 a	3	14	July 1	7	4	46
14	8	3	8	26	8 a	3	6	6	7	2	13	3	4 30 p	5	50
15	8	4	9	27	3 45 p	4	10	8	8 a	4	20	6	6 p	4	55
16	8 a	4	9	28	3 30 p	4	17								

Cambridgeport, 1888 *April* 30.

NUMBER OF SUN-SPOTS, 1884–1886,

By WILLIAM DAWSON.

The object-glass used in these observations has an aperture of 4.6 inches, and about 70 inches focus; it was made by A. Clark & Sons, and mounted equatorially by myself. Previous to May, 1878, I used a direct eye-piece, a two-inch diaphragm over the object-glass, and a red shade on the ocular. Since then I have used a reflecting prism and neutral shade, with full aperture, obtaining finer views. The 100-power eye-piece was generally used, and mostly at from 8 to 9 A.M.

On August 27, 1870, I saw 14 groups and counted 950 spots, with the power of 200; and 300 spots with the power of 50. I think this was the maximum of that period. In 1871–78, I left off counting the spots on account of failing eyesight, simply noting the number of groups, large and small. Observations were much neglected in 1874–77. I estimate that I have seen about 40 different sun-spots with the naked eye — their diameters (*umbrae*) ranging from about 8,000 to 35,000 miles.

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A sort of summary of these observations, up to 1879, was published in the *Kansas City Review*, Vol. III, No. 1 (May, 1879); and the table of observations to July, 1884, was published in the *Sidereal Messenger*, No. 26, p. 171 (August, 1884).

Number of Groups and Spots.

Date.	Hour.	Gp.	Spots	Wt.	Notes.
1884 Aug. 1	8h	4	95	5	v l g, 5l sp W center
	8⅓	5	120	5	v l g, has 80 spots
2	8	5	120	4	" " 75 "
5	9	3	28	3	" near W edge
6	8¼	4	16	4	" gone, faculae
7	8¾	4	12	3	l s East; 1 West
Sept. 2	P.M.	3	11	4	spots all small
8	9	5	40	4	spots in SE quadr
11	9	6	90	4	77 s near center
14	3½	6	48	1	l g near W edge
18	9	6	70	3	4 s v prominent
20	9	7	70	3	
21	8½	7	120	3	l g near center
25	8¼	5	60	3	
26	8⅔	5	55	3	
Oct. 1	11	5	47	2	A l s at E edge
2	9⅓	6	95	5	5 l spots
3	8	6	60	4	
6	8½	4	53	2	1 sp vis naked eye
9	9	3	55	3	l g W of center
10	9½	2	75	4	new g at E edge
11	8⅔	2	72	4	" has 12 s
12	noon	2	50	3	" " 5 s
13	10	2	40	3	l g near W edge
14	10¾	4	16	3	2 new g E edge
16	11	1	10	3	the g near E edge
18	9½	4	44	3	2 g near W edge
20	8⅔	5	28	3	4 g of the 1 on 16th
22	11¼	4	28	3	new g E side
23	11	4	45	2	
25	9	8	80	4	3 v l spots
28	9	4	70?	1	new g at E edge
30	11½	3	85	3	
31	12⅓	3	52	3	
Nov. 6	2⅓	1	1	2	s near W edge
7	9	1	1	3	
8	9	0	0	3	
9	9	2	10	3	1 g near center; 1 E
9	2½	3	25	4	s growing fast
10	10½	4	33	3	s " " in size
11	2	7	47	3	3 new g E side
12	1¾	6	40	3	26 s in 1 g
13	9⅓	7	43	4	24 s " g
14	9⅓	5	50	4	
15	9⅔	6	28	4	l g near W edge
16	9	6	10	4	l s near E edge
16	1	7	14	5	
19	10⅔	3	28	3	
21	10	4	61	4	5 l spots
Dec. 2	10⅓	4	66	4	
4	11	4	43	4	1 s at E edge
8	9½	5	14	3	
18	12½	4	11	1	power 50
26	12½	4	25?	3	l s near center
1885 Jan. 1	9½h	3	5	1	air v tremulous
2	11½	3	9	1	
4	noon	5	40	4	
7	11	3	9	1	power 50
9	10	1	2	3	s little at W side
10	11	1	3	5	
12	2⅓	1	8	3	new g SE
13	noon	1	5	1	
16	11	2	6	1	p 45 2 l s E
25	1	6	44	3	6 l s
28	1	7	25	3	l s at E side
29	12⅓	6	28	4	
Feb. 3	10¼	5	70	3	1 s vis to naked eye
7	10⅔	3	35	1	
8	10	4	50	2	new g E side
13	2	4	30	1	
14	1¼	4	55	3	2 s are l
18	11	4	30	2	
20	12	7	43	3	
23	1	6	21	1	
27	11¼	3	7	3	s all near E edge
Mar. 3	10	6	75	4	v l g at E side
9	10	4	32	4	8 l s W faculae
11	3	5	30	5	l s at E edge
16	11	4	20	4	
22	11	0	0	4	
27	11½	3	40	4	1 g E; 1 W
31	noon	2	40	4	new s at E edge
April 1	9	2	40	4	l g S of center
4		3			several s in each g
5	10	3	35	4	fine grs E and W
6	10½	5	45	3	new g W and 1 E
8	11½	3	53	2	10 l s N of center
12	9⅓	4	83	3	long g W side
20	9½	2	13	3	s all E of center
22	9¼	3	23	3	new g at E edge
27	2	5	20	1	
28	9⅓	5	45	4	l s at E side
May 3	10½	5	30	4	v l s near center
7	10	6	45	2	fine show; s are l
14	8	3	12	5	s all near W side
17	9	2	28	5	s all near E side
18	8¼	4	33	5	v l s E side
19	8⅔	4	34	4	
23	11½	6	50	3	p 50; 5 s are large
28	10	8	52	5	v fine show
29	10⅓	7	28	4	
31	10	5	25	3	2 g at W edge; 2 E
June 2	12⅓	5	45	2	
4	8½	5	85	2	v l s near E edge
8	8	5	60	3	
9	7½	2	52	4	2 s vis to naked eye
11	8½	7	70	5	1 s v easy to naked eye
16	8½	10	150	4	

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Date.	Hour.	Gp.	Spots	Wt.	Notes.
1885 June 19	5^h	4	135	3	l s v easy to naked eye
22	$8\frac{2}{3}$	4	95	3	1 v l g, 1 s vis naked eye
23	$9\frac{2}{3}$	5	100	3	the l s is breaking
30	$7\frac{1}{2}$	5	85	4	l g W side; no l s
July 2	$9\frac{1}{2}$	5	115	4	85 s near E side
3	8	3	130	5	125 s near E side
5	8	3	80	3	11 l s
6	$8\frac{1}{2}$	3	90	3	10 l s
7	$8\frac{1}{2}$	3	80	4	1 s vis to naked eye
12	$7\frac{1}{2}$	4	35	4	
13	$2\frac{1}{4}$	4	40	3	5 s are l
15	$8\frac{1}{2}$	5	63	3	4 l s in 1 penumbra
17	5	7	85	3	l s close to E edge
19	9	6	70?	2	8 s are l
23	9	6	58	4	l s S of center
24	8	6	45	4	" vis to naked eye
25	$7\frac{1}{2}$	5	43	5	" smaller
27	$8\frac{1}{4}$	4	40	3	" still waning
29	8	4	25	2	" close to W edge
Aug. 9	9	4?	57	4	
12	$2\frac{1}{3}$	4	50	3	7 s prominent
13	$2\frac{1}{3}$	5	70	3	new l s at E edge
15	$8\frac{1}{3}$	5	55	3	
16	$8\frac{1}{2}$	4	28	3	
19	8	4	18	2	
20	$8\frac{1}{2}$	4	15	4	
22	10	3	10	3	l s near W edge
23	$9\frac{1}{3}$	3	15	3	
24	8	2	8	1	7 s E; 1 W
26	8	3	34	3	new g W; 1 E
28	$7\frac{1}{2}$	5	64	5	row of g S equator
29	$8\frac{1}{3}$	5	70	3	12 s prominent
30	9	5	63	4	14 s prominent
Sept. 2	$7\frac{3}{4}$	5	58	4	2 l s near center
6	8	4	20	3	7 l s
11	$8\frac{1}{2}$	3	20	5	2 s vis to naked eye
14	9	3	32	3	2 s " " "
15	$8\frac{1}{2}$	3	16	4	2 s " " "
20	9	2	5	4	s all little
22	$7\frac{3}{4}$	3	11	3	
Oct. 4	$7\frac{2}{3}$	3	12	2	1 l s
6	9	3	28	3	v l s S of center
10	3	4	35	3	
11	$8\frac{1}{3}$	4	24	4	
15?		1	1	4	little s E side
30	9	4	27	2	long row of l s
Nov. 3	1	2	3	3	sq s W of center
15	$3\frac{1}{3}$	4	30?	2	1 s vis to naked eye
16	noon	4	18	1	
Dec. 15	2	1	7	1	p 50; air v poor
16	10	1	10	2	s S of center
20	$3\frac{1}{3}$	3	6	1	p 50, 5 s E, 1 W
21	1	3	9	2	
26	$3\frac{2}{3}$	3	11	2	p 50
27	$12\frac{2}{3}$	3	25	3	
1886 Jan. 1	$9\frac{1}{4}$	2	25	4	1 g E; 1 g W
6	noon	3	34	2	l s near center
17	$9\frac{2}{3}$	2	40	1	l s E side
Feb. 1	$1\frac{1}{2}$	1	6	2	g near W side
8	1	3	22	3	l g E of center
16	noon	1	3	3	p 50; g at W edge
1886 Feb. 20	$noon^h$	2	11	2	p 50; grs near center
23	2	0	0	3	
Mar. 1	noon	3	45	3	prominent g E side
3	2	4	70?	2	l s in g E side
4	$1\frac{1}{2}$	5	100?	3	big show of s
6	$11\frac{1}{2}$	6	60	1	p 50; 10 l s
14	9	1	7	3	1 v l s near W edge
15	$9\frac{1}{2}$	2	7	5	best air this winter
16	noon	2	6	2	l s at W edge
19	$9\frac{1}{2}$	4	15	4	
22	11	2	22	3	g each side of center
April 7	10	3	28	2	l s S of center
8	11	3	15	3	
13	$8\frac{2}{3}$	0	0	3	
17	9	2	4	4	l s near E side
20	9	5	17	4	l s at E edge
21	9	5	22	5	4 s are l
23	9	6	25	5	
25	9	4	30	4	l s resembles N Guinea
May 2	10	4	60	4	l g W of center
3	10	4	75	4	
5	$5\frac{1}{2}$	3	55	4	
6	$10\frac{1}{2}$	3	80	5	70 s in 1 g
9	5	1	48	3	
16	8	0	0	5	
18	noon	1	2	5	s are v small
19	8	1	3	4	s all small
19	2	1	4	3	1 pretty l s
20	8	1	4	5	s all small
21	$7\frac{1}{2}$	3	7	4	l s at E edge
23	8	2	4	3	
28	8	3	6	5	
29	8	3	9	5	fine l s 5000 m diam.
30	8	4	25	4	l s 5′ from W edge
31	$8\frac{1}{3}$	5	13	5	great diminution
June 1	$6\frac{3}{4}a$	2	3	2	l s close W edge
4	$7\frac{2}{3}$	3	70	4	l g E
6	$7\frac{1}{2}$	4	55	3	1 s like a bird
14		0	0		
22	$4\frac{1}{2}p$	4	25	4	
23	$8\frac{1}{2}$	4	20	3	
24	$5p$	3	10	4	
25	8	4	10	4	new g at E edge
26	8	2	5	5	new g vanished
27	$5\frac{1}{2}p$	5	16	3	v l s in a new g E
28	8	4	19	4	2 prom. s vanished
29	9	3	30	4	20 s in a semi-circle
30	$8\frac{1}{2}$	3	50	3	l s 8000 m long
July 3	$8\frac{1}{2}$	3	35	3	v l s nearly roumd
4	9	3	35	4	
5	$8\frac{1}{3}$	3	48	5	l s breaking
9		1	2	3	l s near W edge
11	$8\frac{1}{2}$	0	0	4	
12	8	0	0	3	
14	5	2	5	4	s all near W edge
15	8	1	1	3	s at E edge
16	$8\frac{1}{4}$	2	9	4	new s E edge
17	$7\frac{1}{2}$	3	24	4	22 s in 1 g
18	$8\frac{2}{3}$	2	43	4	42 s "
19	$7\frac{1}{2}$	1	50	4	1 s 5000 m diameter
21	$9\frac{1}{4}$	2	45	5	l s near 8000 diameter

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Date.	Hour.	Gp.	Spots	Wt	Notes.
1886 July 22	8^h	2	38	4	l s divided in 3
23	7½	2	35	3	
24	7½	2	35	3	l s divided in 4 s
25	7½	4	28	5	l s near E edge
26	8½	5	20	3	s 1′ from W edge
28	8	4	35	3	6 s v prominent
29	7⅓	4	25	3	a l s breaking
31	7	3	32	3	l g NW center
Aug. 2	7⅔	3	38	4	2 l s
4	8	4	32	4	1 l s
8	7½	1	6	4	g 8′ from W edge
9	7½	1	8	3	
10	8	2	6	3	
11	8	3	10	3	l s E. side
15	5	1	5	3	2 l s N center
19	9	2	3	4	s waning
22	9	1	1	3	little s E
24	4⅓	0	0	3	
25	8⅔	1	5	5	g 10′ from E edge
26	11	1	14	4	2 s are large
27	8	1	14	4	much change
28	8	1	10	4	
29	8	1	6	4	
31	8	1	6	3	new g E; 2 s large
Sept. 1	8½	1	12	3	2 s are l
3	7⅔	1	15	4	4 s are l
4	8	1	24	3	g at center
5	8	1	24	3	
6	8¾	1	15	3	
1886 Sept. 7	11^h	2	19	3	new g below other
8	8½	3	11	2	new s near E edge
10	8⅓	5	15	4	l s at W edge
11	8⅓	3	25	4	
13	8	4	31	2	
17	4	3	31	3	
20	8	2	15	4	
22	5½	1	2	1	p 50; g at center
24	8⅔	0	0	3	no faculae
25	8½	1	5	5	g W; faculae E
29	8	0	0	3	
Oct. 1	9¼	1	2	3	
3	8⅓	1	6	3	
15	4½	1	10	3	
16	10	1	15	4	4 l s
17	8½	1	15	3	4 l s
18	8½	1	13	3	s growing less
20	9¼	0	0	3	
22	9	1	2	3	s near W edge
23	9	1	2	5	l s near E edge
24	9	1	4	3	2 s prominent
31	9	0	0	3	
Nov. 4	8⅓	0	0	3	
23?		0	0	2	
Dec. 1	noon	0	0	3	
5	2½	0	0	2	
7	2	0	0	2	
20	2	1	7	2	g at W edge

Spiceland, Indiana, 1888 *March* 12.

OBSERVATIONS OF SAPPHO (80),

WITH THE 15½-INCH EQUATORIAL OF THE WASHBURN OBSERVATORY,

BY GEORGE C. COMSTOCK.

Date.	Comp. Star.	Madison M.T.	(80) — ✱ R.A.	No. of Comp.	log $p\Delta$	(80) — ✱ Dec.	No. of Comp.	log $p\Delta$
1888 April 2	17	$12^h\ 56^m\ 54^s$	$+1^m\ 38^s.68$	6	8.603			
" 3	17	11 33 7	+0 48.27	6	n9.076			
" "	17	11 33 19				$+4'\ 58''.3$	5	0.861
" 10	13	11 43 45				—3 15.2	6	0.861
" "	13	11 51 59	+0 13.13	9	n8.426			
" 11	13	11 44 36	—0 42.43	8	n8.391			
" "	13	11 45 15				+5 9.2	4	0.859
" 19	8	11 31 55	+0 35.22	8	8.456			
" "	8	11 32 45				+3 42.3	7	0.854

Each comparison in R.A. consists of a transit of planet and star over *three* threads, eye and ear.

The observations have been corrected for differential refraction.

The numbers of the comparison-stars refer to BRYANT's list, *R. Astr. Soc. M.N.* Vol. XLVIII, No. 3.

Approximate places for 1888.0, of the comparison-stars, are

No.	α	δ	
17	$13^h\ 27^m\ 26^s.12$	$-13^\circ\ 40'\ 13''.5$	Weisse's Bessel; Santini
13	13 21 35	—12 35.5	SDM. 12° 3819
8	13 12 56.35	—11 25 30.0	Weisse's Bessel; Santini

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EPHEMERIS OF THE OLBERS COMET,

By N. M. PARRISH.

[Communicated by Prof. Ormond Stone.]

Date.	α	δ	log r	log Δ	Date.	α	δ	log r	log Δ
1888	h m s	° ′			1888	h m s	° ′		
May 5	18 4 7	—13 46.7	0.4797	0.3479	June 3	17 31 42	—17 25.4		
6	3 13	13 53.9			4	30 28	17 32.8		
7	2 18	14 1.1			5	29 15	17 40.2		
8	1 22	13 8.5			6	28 2	17 47.5	0.5238	0.3677
9	0 24	14 15.8	0.4856	0.3475	7	26 49	17 54.8		
10	17 59 25	14 23.3			8	25 35	18 2.0		
11	58 25	14 30.8			9	24 23	18 9.2		
12	57 24	14 38.3			10	23 10	18 16.4	0.5289	0.3742
13	56 21	14 45.8	0.4913	0.3478	11	21 59	18 23.5		
14	55 18	14 53.4			12	20 47	18 30.5		
15	54 14	15 1.0			13	19 37	18 37.5		
16	53 9	15 8.6			14	18 26	18 44.4	0.5340	0.3815
17	52 2	15 16.2	0.4969	0.3489	15	17 16	18 51.3		
18	50 55	15 23.8			16	16 7	18 58.1		
19	49 49	15 31.5			17	14 59	19 4.9		
20	48 38	15 39.1			18	13 50	19 11.6	0.5389	0.3897
21	47 28	15 46.8	0.5025	0.3508	19	12 45	19 18.2		
22	46 18	15 54.4			20	11 39	19 24.8		
23	45 7	16 2.0			21	10 35	19 31.3		
24	43 55	16 9.6			22	9 31	19 37.8	0.5438	0.3986
25	42 43	16 17.2	0.5079	0.3538	23	8 29	19 44.2		
26	41 31	16 24.9			24	7 27	19 50.6		
27	40 18	16 32.6			25	6 26	19 56.9		
28	39 5	16 40.2			26	5 25	20 3.1	0.5487	0.4081
29	37 51	16 47.8	0.5133	0.3574	27	4 27	20 9.2		
30	36 37	16 55.5			28	3 29	20 15.3		
31	35 22	17 3.0			29	2 33	20 21.3		
June 1	34 9	17 10.5			30	17 1 37	—20 27.3	0.5534	0.4182
2	17 32 55	—17 18.0	0.5186	0.3621					

This ephemeris is in continuation of that given by Mr. Muller in No. 167.

The computed brightness for May 5, is 0.18; for May 29, 0.15; and for June 30, 0.09; that of 1887 August 27, being still taken as the unit.

Leander McCormick Observatory, 1888 *May* 8.

OBSERVATIONS OF COMET 1888 *a*,

MADE AT U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

By Prof. E. FRISBY and H. P. TUTTLE.

[Communicated by the Superintendent,]

1888 Washington M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″	s		
Apr. 26 15 18 46.0	1	25 , 5	+0 53.00	—7 38.4	23 14 6.71	+24 28 13.9	*n*9.669	0.669	F
May 1 15 54 58.2	2	15 , 3	—2 26.66	—0 15.3	23 26 25.60	+27 20 33.4	*n*9.693	0.595	T
May 3 15 41 51.3	3	25 , 5	+2 36.73	+5 32.5	23 28 46.38	+27 52 28.5	*n*9.701	0.608	F

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Mean Places for 1888.0 for Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ' "	"	
1	23 13 14.41	—0.70	+24 36 3.2	—10.9	Weisse's Bessel, XXIII, 233, 4
2	23 28 52.83	—0.57	+27 20 59.8	—11.1	" " XXIII, 517
3	23 26 10.23	—0.58	+27 47 7.2	—11.2	" " XXIII, 524

The observation of March 29 (*A.J.* No. 169), was in error 20^s; in place of 21^h 55^m 12^s.0, read 21^h 54^m 52^s.0

OBSERVATIONS OF COMET 1888 *a*,

AT THE ARGENTINE NATIONAL OBSERVATORY,

By JOHN M. THOME.

The accompanying observations were made with the equatorial of 11 inches aperture and the filar micrometer. The object was, throughout the series, a very fine one for observing, and though not imposing to the naked eye, the greatest length of tail being only about 5°, presented a splendid coma and tail in the telescope. During the first half of the series, the tail seemed uniformly dense in breadth, but latterly the sides have faded, and a bright-colored streak, extending from the nucleus, predominated along its axis. The nucleus was elliptical, and in the proportion of 3 to 2. Upon the 18th, the comet, as seen by the naked eye, was as bright as a 3½ mag. star. The observations were all made at the end of the regular night's work, when what LACAILLE called *l'envie de dormir* was very great.

1888 Cordoba M.T.	*	No. Obs.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	' "	h m s	° ' "		
Feb. 23 15 29 1.5	1	8	—0 57.47	— 7 0.6	19 44 21.5	—49 14 34	*n*9.888	*n*0.473
24 16 12 34.6	2	6	—3 18.97	— 6 26.3	19 49 56.97	47 48 28.8	*n*9.868	*n*0.318
25 16 4 28.8	3	6	—2 1.27	+ 0 13.3	19 55 5.50	46 24 19.1	*n*9.860	*n*0.381
27 15 57 32.9	4	10	+0 49.41	— 8 12.6	20 4	43 31	*n*9.840	*n*0.448
28 16 20 38.9	5	9	+0 58.56	—11 23.7	20 9 35.60	42 0 25.5	*n*9.823	*n*0.382
Mar. 6 16 13 10.4	6	11	—0 1.96	— 2 15.7	20 38 16.49	31 23 43.1	*n*9.765	*n*0.532
10 16 43 39.4	7	8	+1 43.35	+ 4 38.8	20 52 51.88	25 14 19.1	*n*9.726	*n*0.503
13 16 23 27.9	8	12	+0 14.08	— 5 12.8	21 3 5.20	20 43 57.4	*n*9.721	*n*0.569
18 16 36 52.0	9	7	+1 38.70	— 8 21.8	21 19 41.64	13 29 54.1	*n*9.696	*n*0.597
21 17 1 43.2	10	7	+0 29.57	+ 4 9.0	21 29 27.70	9 16 16.8	*n*9.671	*n*0.607
26 16 55 46.0	11	8	—0 17.92	— 3 48.9	21 45 20.38	2 49 51.1	*n*9.667	*n*0.647
28 17 11 23.0	12	9	—1 33.66	+ 1 55.7	21 51 38.42	— 0 24 31.4	*n*9.652	*n*0.659
30 17 38 37.0	13	11	—3 1.05	+ 1 38.6	21 57 55.34	+ 1 55 13.4	*n*9.619	*n*0.681

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ' "	"	
1	19 45 21	—2.18	—49 7 41	+7.80	Diff. from Gen. Catal. 27323
2	19 53 18.07	2.13	47 43 9.6	7.05	Arg. Gen. Catal. 27367
3	19 57 8.83	2.07	46 24 39.0	6.62	" " 27459
4	20 4 5	1.96	43 23	5.72	
5	20 8 38.95	1.91	41 49 6.9	5.12	" " 27719
6	20 38 20.05	1.60	31 21 29.9	2.48	" " 28431
7	20 51 7.09	1.44	25 18 58.4	+0.47	Cordoba Zone-Catal. 1631
8	21 2 52.50	1.38	20 38 43.6	—1.01	Arg. Gen. Catal. 29006
9	21 18 4.19	1.26	13 21 29.5	2.80	" " " 29332
10	21 28 59.31	1.18	9 20 21.0	4.80	Weisse's Bessel XXI, 638
11	21 45 39.46	1.10	2 45 56.7	5.55	" " XXI, 1039
12	21 53 13.16	1.08	— 0 26 20.7	6.21	" " XXI, 1208
13	22 0 57.44	—1.05	+ 1 53 41.4	—6.64	Bonner Beobb. VI, +1° 4584

Cordoba, 1888 *March* 31.

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OBSERVED MAXIMA OF *R VIRGINIS* AND *T URSAE MAJORIS*,

BY PAUL S. YENDELL.

R Virginis.

Owing to bad weather, I have obtained only twelve observations of this variable, extending from March 7 to April 27, and indicating a maximum on March 31.

At maximum brightness it was 4 to 5 steps < DM. 9°2549 (*A' Virginis*), or about $6^M.2$.

T Ursae Majoris.

A maximum of this star is indicated by fourteen observations, beginning March 7, and extending until May 2. When first seen, it was estimated to be about $10^M.5$; but its brightness rose rapidly, and with a considerably accelerated increase, until April 3, when it was a rather faint $7^M.5$. It remained at this brightness until April 16, a period of 13 days; the decrease being at first quite rapid. The star will be further watched, in order to follow out the curve of its decrease, and, if possible, fix the minimum.

Dorchester, Mass., 1888 *May* 7.

NEW ASTEROIDS,

A planet of the thirteenth magnitude was discovered by CHARLOIS, at Nice, on the third of May. The observation, telegraphically communicated by the *Science Observer* Code, is as follows:

1888 May 3.5170 Gr. M.T. $\alpha = 205° \; 31' \; 36''$ $\delta = -11° \; 13' \; 43''$. Daily motion, -44^s in α, and 4′ northward.

This is the two hundred seventy-seventh asteroid.

Another was discovered by BORRELLY at Marseilles, who estimated it as of the eleventh magnitude. The observation gives

1888 May 12.4336 Gr. M.T. $\alpha = 247° \; 55' \; 40''$ $\delta = -21° \; 47' \; 6''$ Daily motion, -56^s, and 3′ northward.

This is perhaps *Xantippe*, no. 156.

Asteroids nos. 269 and 273 have received the names *Justitia* and *Atropos* respectively.

NOTICE.

Mr. GINZEL, in Berlin, desires to give notice that he purposes computing the orbit of the Olbers comet (1887*f*), and asks that any yet unpublished observations of this comet be made public as soon as possible.

CORRIGENDA IN No. 171.

Page 18, col. 1, line 12, from bottom, for (13) put (14).
21, col. 1, line 7, for number, put member.
" col. 2, line 20, for equation (19), put equations (19) and (20).
" col. 2, line 21, for d, put Δ

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 173.

VOL. VIII. BOSTON, 1888 JUNE 4. NO. 5.

OBSERVATIONS OF *EUKRATE* (247),

MADE AT THE ARGENTINE NATIONAL OBSERVATORY, CORDOBA,

By JOHN M. THOME.

1887 Cordoba M.T.		$\Delta\alpha$	$\Delta\delta$	Obs.	App. α	log $p\Delta$	App. δ	log $p\Delta$	Red. to app. Eq. in α	in δ	Star
d	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Aug. 17	9 35 16.7	—0 29.51	—3 51.0	10	21 35 22.86	n9.611	—44 4 4.7	0.031	+3.06	+15.91	1
18	9 21 4.5	—1 54.30	—0 57.1	4	21 33 58.00	n9.616	44 1 11.0	9.975	3.07	15.72	1
	10 58 33.9	—2 0.00	—0 47.8	4	52.38	n9.151	1.7	0.266			
19	7 27 43.6	+1 39.10	—2 7.5	6	21 32 40.13	n9.796	43 58 16.1	n9.985	3.08	15.24	2
20	9 44 41.9	+0 5.96	+1 48.5	8	21 32 7.04	n9.513	43 54 20.2	0.125	3.08	15.07	2
24	10 10 43.3	+0 7.74	+10 54.6	10	21 25 35.46	n9.274	43 36 32.9	0.230	3.09	14.13	3
Sept. 3	8 38 50.6	—2 27.31	—5 25.0	8	21 13 10.69	n9.473	42 30 8.7	0.086	3.06	12.11	4
8	9 1 10.7	—0 18.48	+5 30.2	8	21 7 55.91	n9.211	41 46 6.9	0.156	2.99	11.03	5
12	9 39 53.6	—2 20.42	+4 7.4	4	21 4 18.77	7.874	41 6 3.5	n0.147	2.96	10.54	6
14	7 51 8.2	—2 14.55	—2 34.8	6	21 2 46.55	n9.437	40 45 46.2	1.011	2.92	10.21	7
15	7 21 34.3	—1 30.01	—9 27.5	7	21 2 2.79	n9.528	40 35 13.3	9.877	2.91	10.01	8
20	7 6 32.4	—1 50.48	—6 48.4	6	20 58 52.74	n9.495	39 38 32.6	9.847	2.80	9.35	9
21	7 2 20.5	—2 21.03	+4 58.4	3	20 58 22.17	n9.485	39 26 45.9	9.846	2.78	9.25	9
	7 13 55.6	—1 43.50	—5 24.6	3	20 58 20.76	n9.450	39 26 38.8	9.897	2.77	9.26	10
22	7 30 25.8	—2 12.23	+6 38.1	7	20 57 52.02	n9.355	39 14 36.3	9.969	2.76	9.15	10
Oct. 8	11 14 29.5	—0 44.74	—0 42.8	6	20 54 55.35	9.692	35 46 1.7	n9.352	2.42	8.13	11
9	10 51 44.1	+0 49.68	+4 33.6	9	20 55 3.17	9.660	35 32 37.6	n9.886	2.41	8.03	12
10	10 46 22.8	+1 7.23	+4 47.9	7	20 55 11.3	9.656	35 19 11	n9.888	2.39	7.97	13
20	10 11 15.3	+1 15.37	—3 58.2	7	20 58 11.87	9.646	33 1 20.2	n0.026	2.17	7.96	14
Nov. 15	10 48 10.5	+2 51.43	+0 13.3	5	21 11 42.71	9.744	26 52 25.5	n0.536	1.74	8.68	15
16	8 34 5.7	—0 18.82	—4 0.6	7	21 18 19.33	9.598	26 31 14.9	n0.232	1.75	8.82	16
17	7 55 20.0	+0 40.34	+9 58.5	10	21 19 18.48	9.506	26 25 16.9	n0.128	1.74	8.91	16
Dec. 6	8 35 41.6	—2 59.67	—0 59.4	6	21 41 1.83	9.668	21 49 2.1	n0.450	1.60	9.64	17
9	8 23 12.6	+0 16.20	—1 2.4	7	21 44 50.40	9.661	21 4 57.1	n0.453	1.54	9.72	18
14	8 40 20.2	+0 30.92	—7 18.2	10	21 51 21.85	9.688	19 50 43.3	n0.513	1.53	10.07	19
15	8 28 7.6	+1 49.93	+7 29.3	6	21 52 40.86	9.679	—19 35 55.8	n0.502	+1.53	+10.07	19

Adopted Mean Places for 1887.0 of Comparison-Stars.

*	α	δ	Authority.	*	α	δ	Authority.
	h m s	° ′ ″			h m s	° ′ ″	
1	21 35 49.31	—44 0 29.6	Arg. Gen. Catal. 29694	11	20 55 37.67	—35 45 27.0	Cordoba Z. Catal. 1747
2	21 30 57.95	43 56 23.8	" " 29600	12	20 54 11.08	35 37 19.2	Arg. Gen. Catal. 28774
3	21 25 24.63	43 47 41.6	Cordoba Z. Catal. 773	13	20 54 1.7	35 24 7	
4	21 15 34.94	42 24 55.8	" " 465	14	20 56 54.33	32 57 30.0	" " 28849
5	21 8 11.40	41 51 48.1	Arg. Gen. Catal. 29129	15	21 14 32.40	26 52 47.5	Oeltzen's Argel. 21316
6	21 6 36.21	41 10 21.4	" " 29029	16	21 18 36.40	26 35 24.3	Arg. Gen. Catal. 29334
7	21 4 58.18	40 43 21.6	" " 29048	17	21 43 59.90	21 48 12.3	Oeltzen's Argel. 21676
8	21 3 29.89	40 25 55.8	" " 29022	18	21 44 32.66	21 4 4.4	Lalande 22544
9	21 0 40.42	39 31 53.5	" " 28953	19	21 50 49.40	—19 43 35.4	Arg. Gen. Catal. 30022
10	21 0 1.49	—39 21 23.5	" " 28927				

NOTES. — Sept. 8, through clouds. Sept. 21, high wind, telescope unsteady. Dec. 6, 9, 10, very faint. Dec. 15, barely visible.

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A STUDY OF THE RESIDUAL DISCORDANCES FOR *MERCURY*,

BY ORRAY T. SHERMAN.

The C—O for each complete observation of *Mercury*, as given in the published observations of the observatories of Washington (1861–1882), Paris (1856–1881), Radcliffe (1864–1877), and Greenwich (1864–1883), have been converted into their values in longitude and ecliptic polar distance, and gathered into the groups for each thirty degrees of the planet's true anomaly. Each group has again been subdivided according to the position of the earth at the moment of observation, and the resulting means are presented in the following tables. The first column presents the value of the planet's true anomaly. The second and sixth the values of the earth's true anomaly which bound the portion of its orbit occupied at the times of the observations included in the mean. Columns three and seven give the number of observations in each group; columns four and eight the mean of the groups of tabular errors in longitude; columns five and nine the mean of the groups of tabular errors in ecliptic north polar distance.

MEAN VALUES OF C—O FOR *Mercury* FROM OBSERVATIONS AT GREENWICH, RADCLIFFE AND PARIS.

v	Earth's true Anomaly	No. of Obs.	Mean of C—O in Longitude	Mean of C—O in Polar Dist.	Earth's true Anomaly	No. of Obs.	Mean of C—O Longitude	Mean of C—O Polar Dist.
°	° °		″	″	° °		″	″
15	187.8 — 319.3	50	+0.0865	—0.1189	24.7 — 147.6	30	+1.6930	—0.1396
45	200.6 — 330.2	53	+0.4055	—0.2581	73.1 — 172.0	53	+1.3224	—0.4149
75	245.6 — 357.3	37	—0.1973	—0.7750	74.8 — 216.3	46	+1.3534	—0.1647
105	269.2 — 373.9	38	—0.6521	—0.4861	119.9 — 251.7	77	+1.3956	+0.0163
135	299.7 — 63.8	12	—0.9529	—0.2451	133.2 — 270.9	102	+1.1689	—0.1176
165	342.3 — 113.4	26	—0.8389	—0.0854	74.6 — 301.3	54	+1.0393	—0.8567
195	3.2 — 144.5	39	—0.7991	+0.3632	174.8 — 313.6	36	+0.2059	—0.0604
225	8.2 — 170.0	55	—0.7991	—0.0413	178.4 — 363.8	38	+0.7568	+0.2230
255	83.5 — 205.8	56	—0.5488	—0.7846	190.9 — 27.4	16	+0.3376	—1.2194
285	95.7 — 214.0	55	+0.5199	+0.2543	287.7 — 69.7	14	+0.2275	—0.1395
315	127.4 — 240.6	48	+0.1726	+0.3453	341.4 — 106.9	22	+0.7187	—0.1798
345	171.3 — 282.8	47	+0.3626	—0.3213	16.9 — 131.5	28	+0.7170	+0.0094

MEAN VALUES OF C—O FOR *Mercury* FROM OBSERVATIONS AT WASHINGTON.

v	Earth's true Anomaly	No. of Obs.	Mean of C—O in Longitude	Mean of C—O in Polar Dist.	Earth's true Anomaly	No. of Obs.	Mean of C—O in Longitude	Mean of C—O in Polar Dist.
°	° °		″	″	° °		″	″
15	162.9 — 316.8	20	—1.5224	—1.4591	354.9 — 206.8	14	+0.8819	—2.4107
45	219.1 — 332.1	17	—1.3465	—0.8793	42.4 — 184.9	16	+2.4510	—1.5662
75	263.3 — 44.3	24	—2.4602	—0.4630	77.7 — 190.6	23	+1.9949	—1.0433
105	267.3 — 61.1	21	—1.7740	—0.4842	107.1 — 257.4	21	+1.6660	—0.7974
135	337.1 — 70.27	21	—4.3477	—0.3271	119.6 — 279.6	50	+1.0579	—0.5901
165	343.6 — 100.7	30	—4.0054	—0.8794	169.1 — 331.9	37	—0.3283	—0.7593
195	343.6 — 145.3	37	—2.7227	—0.7453	180.6 — 280.8	37	—0.9508	—1.0004
225	51.3 — 172.6	32	—0.9771	+0.1886	217.2 — 291.7	25	—1.1856	—0.5095
255	83.7 — 176.9	29	—0.1149	—0.6188	265.1 — 330.7	18	—1.5000	—1.5516
285	95.9 — 210.5	18	+0.7401	—0.9730	280.4 — 32.4	8	—1.4347	—1.8869
315	116.3 — 256.7	23	+1.8054	—1.1132	278.7 — 67.3	16	—1.1049	—0.6545
345	153.3 — 286.2	18	+0.2257	—0.1914	37.0 — 118.4	7	—0.0031	—2.5874

The meridian observations discussed by LEVERRIER in the *Annales de l'Observatoire*, Vol. V, and also those given in the "Reduction of the Greenwich Observations from 1750–1830," have yielded us similar tables. Neither series have been further discussed, since both contain too few observations, and cover too long an interval.

The Washington observations are referred to WINLOCK'S tables, or practically LEVERRIER'S first results, as published in the additions to the *Connaissance des Temps* for 1848. Those of the remaining observatories are referred to LEVERRIER'S second table published in the *Annales de l'Observatoire de Paris*, Vol. V, 1861. The former presents the simple gravitational hypothesis; the latter contain LEVERRIER'S well known empirical terms. It is upon this latter subject we hope to throw some light. The mean values, recorded above, have been conceived as caused by actual displacements, practically reproduced at each revolution, constant during the period of observation, and lying in the plane of the orbit. The first of these is justified by the existence of the geocentric means; the second is the only form their theory

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can at present take; the third is in accordance with the result of former work upon the planet.

It is also assumed that the values given for the means are essentially the same that would be yielded by an infinite number of observations. We venture to think that the effect of this assumption is readily eliminated from the final result.

Were we to begin anew the discussion, it would be preferable to discuss each observation, and use the mean result; but such did not seem the case when entering the field. The reduction proceeds as follows:

If c be the linear value of the displacement;
r, the distance from earth to *Mercury's* computed place;
r_1, the distance from earth to *Mercury's* observed place;
γ, the angle included between r and r';
P, the perpendicular from the earth upon c;
z, the distance from the foot of the perpendicular to the computed place;

Then we readily obtain from the well known relation $c^2 = r^2 + r_1^2 - 2\,rr' \cos\gamma$,

$$\tan\tfrac{1}{2}\gamma = \frac{cP}{2(r^2+cz)}$$

correct to terms of the order of $(\tan\frac{1}{2}\gamma)^3$, which are entirely negligeable, since γ is extremely small.

Our numbers, however, represent displacement in, and perpendicular to, the plane of the ecliptic. For the latter r^2 becomes $P^2 + z^2$, z is constant, and we may write

$$\gamma \tan 1'' = \frac{cP}{P^2+z^2+cz}$$

the mean value of which we have taken with regard to equal increments of P. The mean with regard to equal increments of the earth's true anomaly, though perhaps preferable, led into elliptic integrals not suited for calculation; but since γ changes very slowly with P, the two may, within the bounds of accuracy which limit this study, be considered interchangeable. Representing by γ_0 the mean value of γ, by c_1 the linear value of the displacement along the perpendicular, by P_1 and P_2 the terminal values of P, and by M the modulus of the common system of logarithms, we have

$$c_1 = \frac{2\gamma_0 \tan 1''(P_1-P_2)M}{\log(P_2^2+z^2+cz)-\log(P_1^2+z^2+cz)}$$

In the application of this, care should be taken that $P_1 - P_2$ equal the arithmetical sum of the total changes in P. By successive approximation we readily obtain values of c, for each group given above, and the mean of the two values for each mean anomaly is then taken.

For the displacements in the plane of the ecliptic, let
β_1 be the true anomaly in the earth's orbit of the planet's projected radius vector;
β, the earth's true anomaly.
c_2, the linear displacement in the ecliptic;
δ, the angle which c_2 makes with the planet's projected radius vector;
ρ, the planet's radius vector;
λ, the planet's latitude;
R, the earth's radius vector:

Then
$$r^2 = R^2 - 2R\rho\cos\lambda\cos(\beta-\beta_1)+\rho^2\cos^2\lambda$$
$$P = R\sin(\beta-(\beta_1+\delta)) - \rho\cos\lambda\sin\delta$$
$$-z = R\cos(\beta-(\beta_1+\delta)) - \rho\cos\lambda\cos\delta$$

and our fundamental equation takes the form

$$\gamma\tan 1'' = \frac{c_2\,(R\sin(\beta-(\beta_1+\delta)) - \rho\cos\lambda\sin\delta}{R^2-2R\rho\cos\lambda\cos(\beta-\beta_1)+\rho^2\cos^2\lambda + c\rho\cos\lambda\cos\delta - Rc\cos(\beta-(\beta_1+\delta))}$$

the mean of which, with regard to β, we have found for each group, by expanding with regard to β, supplying the numerical values of those quantities which depend upon the dimensions of the earth's orbit, and making successive approximations when necessary, we obtain by wholly elementary processes for each mean value of the displacement in longitude an equation of the form

$$\gamma_0\tan 1''(\tan\tfrac{1}{2}\beta_1-\tan\tfrac{1}{2}\beta_2) = c_2(Aa\,(1-\epsilon^2)\sin(\beta_1+\delta)+\epsilon\rho\cos\lambda\sin\delta) + Ba(1-\epsilon^2)\cos(\beta_1+\delta) + C\rho\cos\lambda\sin\delta)$$

when A, B and C are numerical values, a the major semi-axis, and ϵ the eccentricity of the earth's orbit. Expanding this with regard to β, and replacing those terms depending upon the value of the elements of the earth's orbit by their numerical values, and uniting the two equations for each value of the true anomaly, we obtain finally, from the errors in longitude, an equation of the form

$$c_2 = \frac{\gamma_0\tan 1''(\tan\tfrac{1}{2}\beta_2-\tan\tfrac{1}{2}\beta_1)}{D\cos\delta + E\sin\delta}$$

Returning now to the displacements in latitude, we have the condition that the locus of the projected position of the displaced planet is parallel to the line of intersection of the planes of the two orbits; or that this locus crosses the projected radius at an angle ω. We also have, as will readily be seen, the point of intersection from the calculated planet's projected position equal to $c_1\cot\lambda$; and since c_2 must join this locus with the projected position of the calculated planet, we have

$$c_2 = \frac{c_1\cot\lambda\sin\omega}{\cos(90°\pm(\omega-\delta))} = \frac{c_1\cot\lambda}{\pm\cos\delta+\cot\omega\sin\delta}$$

Equating with the equation obtained from longitudes, we have at once values for c_2 and δ, from which the values of δv and δr, the ecliptic values of the displacement in true anomaly and radius vector at once follow. These are tabulated as follows:

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Corrections to be Applied to the Ecliptic Position of *Mercury*, as Calculated by LeVerrier's Second Table, to obtain the Position given by Meridian Observations.

v	δv	δr
15°	—1″.8097	—0.0000048
45	+2.2303	—0.0000052
75	+3.8814	—0.0000134
105	+1.4329	—0.0000070
135	+3.3773	—0.0000100
165	+6.0296	+0.0000446
195	+2.4717	—0.0000022
225	+0.3836	—0.0000002
255	—1.2062	+0.0000391
285	+1.3905	—0.0000008
315	+1.5319	—0.0000012
345	—3.9753	—0.0000005
Mean	+1″.3948	+0.0000031

The number of observations referred to LeVerrier's first table is so small that it has seemed desirable to combine the results for each quadrant. The values are as follows:

Corrections to be Added to the Ecliptic Position of *Mercury*, as Deduced from LeVerrier's First Table, to obtain its Position yielded by Meridian Observations.

v	δv	δr
45°	+10.083	—0.0000603
135	+10.755	+0.0000084
225	+ 9.807	+0.0000153
315	+ 6.779	+0.0000928
Mean	+9″.3560	+0.0000141

The corrections to the first table refer to the date 1872.3; those to the second refer to 1871.13.

It will be seen that each table contains a fairly regular variation about a constant term. On account of an uncertainty as to the date from which the corrections to the first table should be counted, we are constrained to employ the constant term and variation of the second table, using the results of the first table only for general corroboration.

The mean value of dv indicates an increment of the movement of *Mercury's* perihelion by 0″.0660, making it +44″.20 for a century, a value slightly higher than that given by Newcomb, +42″.95, which depended upon a different series of observations. The constant term of dv, depending upon the single extremely large value at 255°, has not seemed real.

Finally we present the periodic variation in orbit.

v	δv LeVerrier's 2d Table.		δv 1st Table.	δr
15°	—2″.204			—0.0000048
45	+0.836	+0″.381	+0″.727	—0.0000052
75	+2.487			—0.0000134
105	+0.034			—0.0000078
135	+1.982	+2.217	+1.399	—0.0000100
165	+4.635			+0.0000446
195	+1.107			—0.0000022
225	—0.112	—0.445	+0.247	—0.0000002
255	—2.401			+0.0000398
285	—0.004			—0.0000008
315	+0.137	—1.746	—2.587	—0.0000012
345	—5.370			—0.0000005

It will be seen that the planet receives, when between 330° and 360° of true anomaly, a disturbance whose immediate effect is a considerable disturbance of its orbital velocity, so that the planet passes through perihelion later than was expected. The secondary effect appears to be to draw the planet nearer the sun, and increase its orbital velocity; so that the planet passes beyond its calculated place near aphelion, passes its aphelion slightly before the calculated position, and suffers a secondary effect of a similar character in passing from aphelion towards perihelion.

Although this action is such as to suggest a strong opinion as to its cause, I beg to delay the discussion thereof till I shall present certain relations which are found to exist among the elements of Encke's comet.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 a,

MADE AT THE DUDLEY OBSERVATORY,

By LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
Apr. 6d 16h 49m 42s	4	14, 14	+0m 0s.92	—1′ 26″.4	22h 19m 9s.56	+ 9° 12′ 55″.2	n9.605	0.738
" 18 15 47 25	5	15, 5	—3 9.01	—1 53.2	22 53 14.28	19 12 5.1	n9.654	0.717
" 28 16 9 14	6	9, 3	—0 51.33	+5 52.2	23 19 9.27	25 39 54.6	n9.655	0.643
May 2 15 8 47	7	15, 5	+2 32.73	+4 27.5	23 28 42.20	27 51 25.1	n9.688	0.692
" 13 15 10 37	8	18, 6	—0 41.36	+0 46.9	23 53 5.04	33 6 45.8	n9.705	0.630
" 21 15 32 40	9	15, 5	—5 1.45	—0 3.7	0 8 52.84	+36 20 13.3	n9.701	0.532

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Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
4	22 19 9.56	—0.93	+ 9 12 55.2	— 8.1	[Bessel], [Lamont] and Grant
5	22 56 24.09	0.80	19 14 8.3	10.0	Lal. and Comp. with DM. + 19° 5027
6	23 20 1.27	0.67	25 34 13.4	11.0	Bessel Zone 321 (Weisse 377)
7	23 26 10.05	0.58	27 51 25.1	11.2	Weisse 524 and Rümker 11292
8	23 53 46.84	0.44	33 6 10.8	11.9	Struve 2861 and Leiden A.G. Zones.
9	0 13 54.56	—0.27	+36 20 28.7	—11.7	Weisse's Bessel 319

For these observations the position-angle of the tail was nearly 270°; and this circumstance, together with an apparent actual elongation of the central condensation of the head of the comet, seems to favor the existence of considerable systematic errors in the observed right-ascensions. I intended always to observe the following and brightest part of the central condensation.

A proper motion of —0ˢ.008 and —0″.11 was applied in deducing the place of star No. 8, using the two observations of Lalande to aid in determining this quantity. The star is double, and the mean was observed.

To obtain a more reliable position of No. 5, I also measured its difference from Weisse's Bessel 1356. But the latter appears to be affected with a proper motion of about +0ˢ.02; +0″.1; and as there is no published position of this star at my disposition later than Weisse's, the comparison could not be used.

May 21. The appearance of the comet is transformed. Hitherto, the tail has been narrow and very bright along the axis; and the head has been small and elongated in the direction of the tail. Now, however, the tail has become broad and faint, and of uniform brightness across its breadth. There appears to be a bright outstreaming from the head in the direction ($p = 90°$) at right angles to the axis of the tail. These wings are perhaps 20″ in breadth, and 40″ in length on each side of the nucleus, and convex toward the following side (away from the tail). The boundary and contrast in brightness between the head and tail is very strongly marked. The nucleus is very much brighter than I have seen it during the month preceding. It is fully a quarter of a magnitude brighter than Lal. 330 (the comparison-star), and is decidedly star-like, with an intense light. The tail could not be traced beyond 15′ from the head. The general appearance of the head is that of a nearly rectangular nebulous mass of bright light about 90″ long and 20″ broad, with a star-like nucleus (of magnitude 7.0) just preceding the center.

OBSERVATIONS OF SAPPHO (80),

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

By Prof. E. FRISBY.

[Communicated by the Superintendent.]

1888 Washington M.T.	*	No. Comp.	(80) — * R.A.	Dec.	log pΔ for α	for δ
d h m s			m s	′ ″	s	″
April 3 11 17 15.4	17	20 , 4	+0 49.64	+4 39.3	n9.205	0.839
4 11 26 7.9	14	20 , 4	+3 20.83	—2 27.4	n9.125	0.777
7 10 37 28.2	16	20 , 4	—2 9.93	+3 41.7	n9.299	0.779
14 10 50 7.8	10	20 , 4	+1 55.53	—6 0.5	n9.033	0.749
" 10 50 7.8	11	20 , 4	—2 38.83	+1 56.5		
19 10 13 45.2	8	10 , 2	+0 40.08	+3 34.0	n9.118	0.827

The numbers of the comparison-stars refer to Bryant's list, *M.N. Astr. Soc.* Vol. XLIII, No. 3.

Positions of Comparison-Stars of 1888.0.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
17	13 27 26.12	+1.27	—13 40 13.5	—5.2	Weisse, Santini
14	24 0.46	1.28	13 25 21.0	5.1.	Weisse, Santini, Lamont
16	25 47	1.30	13 8.6	5.2	DM. —12° 3834
10	16 12.96	1.32	11 59 32.0	5.4	Gould, Paris 1870
11	20 48.35	1.32	12 7 27.8	5.4	Gould, Yarnall, (*i Virginis*)
8	12 56.35	+1.33	—11 25 30.0	—6.4	Weisse, Santini

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EPHEMERIS OF COMET 1888 *a* (SAWERTHAL),

CONTINUED FROM No. 171, BY LEWIS BOSS.

The following ephemeris of comet 1888 *a* is calculated from the elliptic elements in No. 171 of the *Astronomical Journal*. From an observation of May 21, at 20h Greenwich mean time, the correction of the ephemeris on that date was —2s.2 and —8″, and is very slowly increasing. Taking the brightness at discovery as the unit, the brightness on June 15 will be 0.059 ; on July 15, 0.029 ; and on Aug. 14, 0.019. The positions are for Greenwich 12h of the corresponding dates.

1888		App. α	App. δ	log r	log Δ
		h m s	° ′ ″		
June	15.5	0 46 47.5	+44 9 1	0.24921	0.30240
	16.5	0 48 2.9	44 25 3		
	17.5	0 49 6.6	44 40 53	0.25607	0.30524
	18.5	0 50 13.5	44 56 31		
	19.5	0 51 18.6	45 11 59	0.26281	0.30784
	20.5	0 52 21.8	45 27 16		
	21.5	0 53 23.2	45 42 23	0.26942	0.31036
	22.5	0 54 22.8	45 57 19		
	23.5	0 55 20.5	46 12 4	0.27591	0.31275
	24.5	0 56 16.3	46 26 40		
	25.5	0 57 10.2	46 41 6	0.28229	0.31501
	26.5	0 58 2.1	46 55 22		
	27.5	0 58 52.1	47 9 28	0.28856	0.31715
	28.5	0 59 40.2	47 23 24		
	29.5	1 0 26.2	47 37 10	0.29472	0.31918
	30.5	1 1 10.2	47 50 47		
July	1.5	1 1 52.2	48 4 15	0.30077	0.32109
	2.5	1 2 32.1	48 17 33		
	3.5	1 3 10.0	48 30 42	0.30672	0.32290
	4.5	1 3 45.7	48 43 42		
	5.5	1 4 19.3	48 56 32	0.31257	0.32459
	6.5	1 4 50.7	49 9 12		
	7.5	1 5 20.0	49 21 43	0.31832	0.32619
	8.5	1 5 47.0	49 34 4		
	9.5	1 6 11.9	49 46 16	0.32398	0.32770
	10.5	1 6 34.4	49 58 18		
July	11.5	1 6 54.7	50 10 9	0.32955	0.32911
	12.5	1 7 12.7	50 21 51		
	13.5	1 7 28.4	50 33 23	0.33503	0.33044
	14.5	1 7 41.8	50 44 45		
	15.5	1 7 52.8	50 55 57	0.34043	0.33169
	16.5	1 8 1.5	51 6 58		
	17.5	1 8 7.8	51 17 48	0.34574	0.33287
	18.5	1 8 11.7	51 28 28		
	19.5	1 8 13.2	51 38 57	0.35097	0.33398
	20.5	1 8 12.2	51 49 15		
	21.5	1 8 8.9	51 59 21	0.35612	0.33503
	22.5	1 8 3.0	52 9 16		
	23.5	1 7 54.7	52 19 0	0.36119	0.33602
	24.5	1 7 44.0	52 28 32		
	25.5	1 7 30.7	52 37 52	0.36619	0.33696
	26.5	1 7 14.9	52 47 0		
	27.5	1 6 56.6	52 55 55	0.37111	0.33785
	28.5	1 6 35.7	53 4 37		
	29.5	1 6 12.3	53 13 7	0.37597	0.33870
	30.5	1 5 46.4	53 21 23		
	31.5	1 5 17.9	53 29 25	0.38075	0.33952
Aug.	1.5	1 4 46.9	53 37 13		
	2.5	1 4 13.3	53 44 47	0.38547	0.34030
	3.5	1 3 37.2	53 52 6		
	4.5	1 2 58.5	53 59 10	0.39012	0.34107
	5.5	1 2 17.2	54 5 59		
	6.5	1 1 33.5	54 12 31	0.39471	0.34182
	7.5	1 0 47.2	54 18 47		
	8.5	0 59 58.4	54 24 47	0.39923	0.34256
	9.5	0 59 7.2	54 30 29		
	10.5	0 58 13.5	54 35 53	0.40369	0.34330
	11.5	0 57 17.5	54 41 0		
	12.5	0 56 19.1	54 45 49	0.40810	0.34405
	13.5	0 55 18.4	54 50 19		
	14.5	0 54 15.4	54 54 31	0.41244	0.34480

OBSERVATION OF COMET 1888 *a*,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

BY H. P. TUTTLE.

1888	Washington M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
May 20d	15h 24m 58s.8	1	10 , 2	+4m 5s.99	—2′ 42″.4	0h 7m 1s.18	+35° 57′ 8″.6	n9.731	0.504

Mean Place of Comparison-Star for 1888.0.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	0h 2m 55s.51	—0s.32	+36° 0′ 33″.4	—12″.4	Weisse's Bessel XXIII, 477

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OBSERVED MAXIMA AND MINIMA OF *T* AND *U MONOCEROTIS*, 1888,

By PAUL S. YENDELL.

T Monocerotis. 2249

A series of thirty-seven observations of this star was obtained this year, extending from Feb. 15 to May 7. Three maxima and three minima are shown by these observations, as follows:

Observed Maxima. Cambridge M.T.		Observed Minima. Cambridge M.T.	
1888 February	19.2	1888 March	7.13
March	18.28	April	3.5
April	13.9	"	30.2

The above times were obtained by Pogson's method from a drawing of the light-curve shown by all the observations.

Dorchester, 1888 *May* 24.

U Monocerotis. 2676

Forty-four observations of this star, beginning Feb. 6, and ending May 9, show the following times of maxima and minima:

Observed Maxima. Cambridge M.T.		Observed Minima. Cambridge M.T.	
1888 March	9.52	1888 February	28.2
April	29.74	April	9.36

These times were obtained in the same manner as were those of *T Monocerotis*, given above; and although both series were much interrupted by weather and moonlight, all the maxima and minima may be considered to be well-determined.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *a*,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY WITH THE 10-INCH EQUATORIAL,

By Prof. F. P. LEAVENWORTH and H. V. GUMMERE.

1888 Haverford M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
Mar. 29 16ʰ 55ᵐ 6ˢ	1	9 , 1	+0ᵐ 4.80ˢ	+5′ 54.5″	21ʰ 54ᵐ 48.72ˢ	+ 0° 46′ 41.0″	n9.621	0.750	L
" 16 55 6	2	9 , 2	+0 2.58	—0 12.7	21 54 48.67	0 46 44.4	n9.621	0.750	L
30 16 58 40	3	12 , 3	—3 1.63	+1 54.5	21 57 54.58	1 55 29.9	n9.617	0.745	L
Apr. 16 16 23 29	4	18	+0 28.24	–	22 47 51.30	–	n9.650	–	L
" 15 40 15	4	3	–	+ 7 21.2	–	17 43 23.5	–	0.704	L
23 16 5 48	5	6 , 2	+3 44.17	+12 4.0	23 6 32.00	22 37 16.7	n9.681	0.622	L
" 16 14 33	6	3 , 3	—1 13.62	— 6 5.2	23 6 33.21	22 37 36.8	n9.681	0.622	L
24 15 17 16	7	26 , 7	—0 48.31	— 1 9.0	23 9 1.59	23 14 15.1	n9.690	0.693	L
25 16 14 2	8	27 , 5	+1 30.58	+ 4 25.6	23 11 40.37	23 53 6.7	n9.666	0.624	G
26 16 1 48	9	24 , 3	+0 57.12	— 6 31.3	23 14 10.66	24 29 20.9	n9.631	0.631	L
" 16 9 22	10	9 , 4	—2 2.80	— 2 22.5	23 14 11.36	24 29 33.2	n9.631	0.631	L
" 16 5 35	11	12 , 2	—2 7.83	— 6 55.4	23 14 10.67	+24 29 25.6	n9.631	0.631	L

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	21ʰ 54ᵐ 44.98ˢ	—1.06ˢ	+ 0° 40′ 52.9″	— 6.4″	Harvard Stand. Cat. bet. 0° and +1°
2	21 54 47.15	1.06	0 47 3.5	6.4	Weisse's Bessel
3	22 0 57.26	1.05	1 53 42.0	6.6	¼(Lam.+ Bonn + 2 Schjellerup)
4	22 47 23.86	0.80	17 36 12.0	9.7	Bonn Obs. VI + 17° 4822
5	23 2 48.55	0.72	22 25 23.3	10.6	Weisse's Bessell 1400
6	23 7 47.57	0.74	22 43 52.6	10.6	Bonn Obs. VI + 22° 4793
7	23 9 50.63	0.73	23 15 34.8	10.7	Weisse's Bessell 154
8	23 10 10.46	0.67	23 48 52.1	11.0	Weisse's Bessel 161
9	23 13 14.24	0.70	24 36 3.1	10.9	Weisse's Bessel 233
10	23 16 14.87	0.71	24 32 6.6	10.9	Weisse's Bessel 299
11	23 16 19.21	—0.71	+24 36 31.9	—10.9	½(Weisse's Bessel + Rümker)

March 30. Nucleus elongated, or perhaps double.

I am indebted to Prof. Edgar Frisby and Mr. Frank Muller, for positions of some of the star-places.

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NEW ASTEROID.

A planet of the twelfth magnitude was discovered May 16 by Palisa, at Vienna. Its position was

1888 May 16.5483 Gr. M.T. $\alpha = 245^\circ\ 16'\ 56''$ $\delta = 21^\circ\ 35'\ 12''$ Daily motion —56ˢ in α and 1′ southward.

This will be No. 279, should that found by Borrelly, May 12, prove not to be *Xantippe*.

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE,

By S. C. CHANDLER.

Approximate Greenwich M.T., 1888.

July	d	h
U Coron. Bor.	1	13
U Ophiuchi	1	20
Algol	1	21
U Ophiuchi	2	16
U Ophiuchi	3	12
Y Cygni	3	17
Algol	4	18
U Cephei	5	10
δ Librae	5	14
Y Cygni	6	17
U Ophiuchi	6	21
Algol	7	15
U Ophiuchi	7	17
U Coron. Bor.	8	12
U Ophiuchi	8	13
U Ophiuchi	9	9
Y Cygni	9	17
U Cephei	10	10
Algol	10	12
δ Librae	12	14
Y Cygni	12	17
U Ophiuchi	12	18
Algol	13	9
U Ophiuchi	13	14
U Ophiuchi	14	10
λ Tauri	14	23
U Coron. Bor.	15	10
U Cephei	15	10
Y Cygni	15	17
U Ophiuchi	17	18
U Ophiuchi	18	15
Y Cygni	18	17
λ Tauri	18	22

July	d	h
U Ophiuchi	19	11
δ Librae	19	14
U Cephei	20	9
Y Cygni	21	17
Algol	21	23
λ Tauri	22	21
U Ophiuchi	23	15
U Ophiuchi	24	12
Y Cygni	24	17
Algol	24	20
U Cephei	25	9
Librae	26	13
λ Tauri	26	20
Y Cygni	27	16
Algol	27	17
U Ophiuchi	28	16
U Ophiuchi	29	12
U Cephei	30	9
Algol	30	14
Y Cygni	30	16
λ Tauri	30	19
August		
U Coron. Bor.	1	16
Algol	2	10
δ Librae	2	13
Y Cygni	2	16
U Ophiuchi	2	17
U Ophiuchi	3	13
λ Tauri	3	17
U Ophiuchi	4	9
Y Cygni	5	16
λ Tauri	7	16

August	d	h
U Ophiuchi	7	17
U Ophiuchi	8	14
U Coron. Bor.	8	14
Y Cygni	8	16
U Ophiuchi	9	10
δ Librae	9	12
λ Tauri	11	15
Y Cygni	11	16
U Ophiuchi	12	18
U Ophiuchi	13	15
U Ophiuchi	14	11
Y Cygni	14	16
U Coron. Bor.	15	11
λ Tauri	15	14
δ Librae	16	12
Algol	16	18
Y Cygni	17	16
U Ophiuchi	18	15
U Ophiuchi	19	11
λ Tauri	19	13
Algol	19	15
U Ophiuchi	20	8
Y Cygni	20	16
U Coron. Bor.	22	9
Algol	22	12
δ Librae	23	12
Y Cygni	23	16
U Ophiuchi	23	16
U Ophiuchi	24	12
U Ophiuchi	25	8
Algol	25	9
Y Cygni	26	16

August	d	h
U Ophiuchi	29	13
Y Cygni	29	16
U Ophiuchi	30	9
δ Librae	30	11
September		
Y Cygni	1	16
Algol	2	23
U Ophiuchi	3	14
U Ophiuchi	4	10
Y Cygni	4	16
Algol	5	20
δ Librae	6	11
Y Cygni	7	16
U Ophiuchi	8	14
U Coron. Bor.	8	15
Algol	8	17
U Ophiuchi	9	11
Y Cygni	10	15
Algol	11	14
δ Librae	13	10
Y Cygni	13	15
U Ophiuchi	13	15
Algol	14	11
U Ophiuchi	14	11
U Coron. Bor.	15	13
Y Cygni	16	15
U Ophiuchi	19	12
Y Cygni	19	15
U Ophiuchi	20	8
δ Librae	20	10
U Coron. Bor.	22	11

September	d	h
Y Cygni	22	15
U Ophiuchi	24	13
U Ophiuchi	25	9
Y Cygni	25	15
Algol	25	22
δ Librae	27	9
Y Cygni	28	15
Algol	28	19
U Coron. Bor.	29	8
U Ophiuchi	29	14
U Ophiuchi	30	10
October		
Y Cygni	1	15
Algol	1	15
U Coron. Bor.	2	19
Algol	4	12
Y Cygni	4	15
U Ophiuchi	5	11
U Cephei	5	16
U Ophiuchi	6	7
Algol	7	9
Y Cygni	7	15
U Coron. Bor.	9	17
Algol	10	6
U Ophiuchi	10	11
Y Cygni	10	15
U Cephei	10	16
U Ophiuchi	11	7
Y Cygni	13	15
λ Tauri	13	21
U Cephei	13	15

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THE

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ORBITS OF AEROLITES,

By H. A. NEWTON.

At the recent meeting of the National Academy of Sciences, I presented certain conclusions, derived from a collation of the statements of the observers of those stonefalls which are represented by specimens now in our museums. I assumed, as already proved, a relation between the comets and the meteoroids of various kinds; so that we may, in general and as a first approximation, assign to the latter bodies, on approaching the earth, a velocity in their orbits about the sun not greater than that of a parabola, and not less than that of the comet of shortest period. This gives them velocities between 1.414 and 1.244; the earth's mean velocity being unity. For uniformity of reduction, however, I used the maximum velocity in my reductions. A smaller velocity would in general strengthen the argument for the conclusions arrived at.

For 116 stonefalls, I was able to obtain some statement indicating the direction through the air of the fireball, or else the direction from which the stones came. For single meteors the actual path is certainly very uncertain. But I feel considerable confidence in the conclusions derived from the statement of all the falls, when the results are collated. If the several statements, when single, are accepted as correct, and if the most probable direction of the meteor be deduced when more than a single observation is reported, and if the velocity be assumed to be that belonging to a parabolic orbit, then it is found that 109 of the 116 bodies were moving about the sun in orbits having inclinations less than 90°, against 7 moving in orbits inclined more than 90°. For 94 other stonefalls only the time of day is given, with no indication of the direction of the meteor's motion. These cases, so far as they give any evidence, confirm the conclusions obtained from the 116 stonefalls before considered.

Again, treating individually the 116 paths, it appears that if we change the paths each through 180° of azimuth, the altitudes remaining unchanged, the point from which the meteor is moving will be thus carried away from the point from which the earth is moving in 70 cases, while the two points will approach each other in 44 cases. This implies that the reason why stones following the earth have been secured in so much larger numbers than those meeting the earth is not due entirely, or even mainly, to the times of day at which men from their habits of living, and of being out of doors, are likely to secure the stones. Either fewer stones come into the air, meeting the earth in its motion, or else such stones are in general destroyed in coming through the air by reason of their large velocities. But large velocities are not always fatal to the integrity of these bodies, and it seems more reasonable to believe that there are many more stones actually following the earth in its orbit about the sun than there are meeting the earth. Hence these bodies seem to have closer relations with the periodic comets than with comets of long period.

Another fact of interest is obtained by this discussion. Of the 116 orbits obtained as above, 103 have perihelion-distances greater than 0.5. With this may be compared some results from SCHIAPARELLI's table of orbits corresponding to 189 radiants of shooting stars observed by ZEZIOLI (*Entwurf einer Theorie der Sternschnuppen*, pp. 84–93, Stettin, 1871). In these orbits, 18 perihelion-distances were less than 0.5, against 169 greater than 0.5.

Yale University, 1888 *June* 12.

SOME OBSERVATIONS OF VARIABLE STARS IN 1887,

By EDWIN F. SAWYER.

1. *R Virginis.*

This star was observed from May 12 to July 13, the observations numbering 13. When first seen, on May 12, *R* was = DM. 8°,2626, or about $8^{M}.5$. The increase of light was rapid and uniform, a maximum being passed about June 17. Maximum brightness 3 steps > DM. 8°,2619, and 5 steps <

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A STUDY OF THE RESIDUAL DISCORDANCES FOR *MERCURY*,

By ORRAY T. SHERMAN.

The C—O for each complete observation of *Mercury*, as given in the published observations of the observatories of Washington (1861–1882), Paris (1856–1881), Radcliffe (1864–1877), and Greenwich (1864–1883), have been converted into their values in longitude and ecliptic polar distance, and gathered into the groups for each thirty degrees of the planet's true anomaly. Each group has again been subdivided according to the position of the earth at the moment of observation, and the resulting means are presented in the following tables. The first column presents the value of the planet's true anomaly. The second and sixth the values of the earth's true anomaly which bound the portion of its orbit occupied at the times of the observations included in the mean. Columns three and seven give the number of observations in each group; columns four and eight the mean of the groups of tabular errors in longitude; columns five and nine the mean of the groups of tabular errors in ecliptic north polar distance.

Mean Values of C—O for *Mercury* from Observations at Greenwich, Radcliffe and Paris.

v	Earth's true Anomaly	No. of Obs.	Mean of C—O in Longitude	Polar Dist.	Earth's true Anomaly	No. of Obs.	Mean of C—O Longitude	Polar Dist.
°	° °		″	″	° °		″	″
15	187.8 — 319.3	50	+0.0865	—0.1189	24.7 — 147.6	30	+1.6930	—0.1396
45	200.6 — 330.2	53	+0.4055	—0.2581	73.1 — 172.0	53	+1.3224	—0.4149
75	245.6 — 357.3	37	—0.1973	—0.7750	74.8 — 216.3	46	+1.3534	—0.1647
105	269.2 — 373.9	38	—0.6521	—0.4861	119.9 — 251.7	77	+1.3956	+0.0163
135	299.7 — 63.8	12	—0.9529	—0.2451	133.2 — 270.9	102	+1.1689	—0.1176
165	342.3 — 113.4	26	—0.8389	—0.0854	74.6 — 301.3	54	+1.0393	—0.8567
195	3.2 — 144.5	39	—0.7991	+0.3632	174.8 — 313.6	36	+0.2059	—0.0604
225	8.2 — 170.0	55	—0.7991	—0.0413	178.4 — 363.8	38	+0.7568	+0.2230
255	83.5 — 205.8	56	—0.5488	—0.7846	190.9 — 27.4	16	+0.3376	—1.2194
285	95.7 — 214.0	55	+0.5199	+0.2543	287.7 — 69.7	14	+0.2275	—0.1395
315	127.4 — 240.6	48	+0.1726	+0.3453	341.4 — 106.9	22	+0.7187	—0.1798
345	171.3 — 282.8	47	+0.3626	—0.3213	16.9 — 131.5	28	+0.7170	+0.0094

Mean Values of C—O for *Mercury* from Observations at Washington.

v	Earth's true Anomaly	No. of Obs.	Mean of C—O in Longitude	Polar Dist.	Earth's true Anomaly	No. of Obs.	Mean of C—O in Longitude	Polar Dist.
°	° °		″	″	° °		″	″
15	162.9 — 316.8	20	—1.5224	—1.4591	354.9 — 206.8	14	+0.8819	—2.4107
45	219.1 — 332.1	17	—1.3465	—0.8793	42.4 — 184.9	16	+2.4510	—1.5662
75	263.3 — 44.3	24	—2.4602	—0.4630	77.7 — 190.6	23	+1.9949	—1.0433
105	267.3 — 61.1	21	—1.7740	—0.4842	107.1 — 257.4	21	+1.6660	—0.7974
135	337.1 — 70.27	21	—4.3477	—0.3271	119.6 — 279.6	50	+1.0579	—0.5901
165	343.6 — 100.7	30	—4.0054	—0.8794	169.1 — 331.9	37	—0.3283	—0.7593
195	343.6 — 145.3	37	—2.7227	—0.7453	180.6 — 280.8	37	—0.9508	—1.0004
225	51.3 — 172.6	32	—0.9771	+0.1886	217.2 — 291.7	25	—1.1856	—0.5095
255	83.7 — 176.9	29	—0.1149	—0.6188	265.1 — 330.7	18	—1.5000	—1.5516
285	95.9 — 210.5	18	+0.7401	—0.9730	280.4 — 32.4	8	—1.4347	—1.8869
315	116.3 — 256.7	23	+1.8054	—1.1132	278.7 — 67.3	16	—1.1049	—0.6545
345	153.3 — 286.2	18	+0.2257	—0.1914	37.0 — 118.4	7	—0.0031	—2.5874

The meridian observations discussed by LeVerrier in the *Annales de l'Observatoire*, Vol. V, and also those given in the "Reduction of the Greenwich Observations from 1750–1830," have yielded us similar tables. Neither series have been further discussed, since both contain too few observations, and cover too long an interval.

The Washington observations are referred to Winlock's tables, or practically LeVerrier's first results, as published in the additions to the *Connaissance des Temps* for 1848. Those of the remaining observatories are referred to LeVerrier's second table published in the *Annales de l'Observatoire de Paris*, Vol. V, 1861. The former presents the simple gravitational hypothesis; the latter contain LeVerrier's well known empirical terms. It is upon this latter subject we hope to throw some light. The mean values, recorded above, have been conceived as caused by actual displacements, practically reproduced at each revolution, constant during the period of observation, and lying in the plane of the orbit. The first of these is justified by the existence of the geocentric means; the second is the only form their theory

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can at present take; the third is in accordance with the result of former work upon the planet.

It is also assumed that the values given for the means are essentially the same that would be yielded by an infinite number of observations. We venture to think that the effect of this assumption is readily eliminated from the final result.

Were we to begin anew the discussion, it would be preferable to discuss each observation, and use the mean result; but such did not seem the case when entering the field. The reduction proceeds as follows:

If c be the linear value of the displacement;

r, the distance from earth to *Mercury's* computed place;

r_1, the distance from earth to *Mercury's* observed place;

γ, the angle included between r and r';

P, the perpendicular from the earth upon c;

z, the distance from the foot of the perpendicular to the computed place;

Then we readily obtain from the well known relation $c^2 = r^2 + r_1^2 - 2\,rr' \cos\gamma$,

$$\tan\tfrac{1}{2}\gamma = \frac{cP}{2(r^2+cz)}$$

correct to terms of the order of $(\tan\frac{1}{2}\gamma)^3$, which are entirely negligeable, since γ is extremely small.

Our numbers, however, represent displacement in, and perpendicular to, the plane of the ecliptic. For the latter r^2 becomes $P^2 + z^2$, z is constant, and we may write

$$\gamma \tan 1'' = \frac{cP}{P^2+z^2+cz}$$

the mean value of which we have taken with regard to equal increments of P. The mean with regard to equal increments of the earth's true anomaly, though perhaps preferable, led into elliptic integrals not suited for calculation; but since γ changes very slowly with P, the two may, within the bounds of accuracy which limit this study, be considered interchangeable. Representing by γ_0 the mean value of γ, by c_1 the linear value of the displacement along the perpendicular, by P_1 and P_2 the terminal values of P, and by M the modulus of the common system of logarithms, we have

$$c_1 = \frac{2\gamma_0 \tan 1''(P_1 - P_2)M}{\log(P_2^2+z^2+cz) - \log(P_1^2+z^2+cz)}$$

In the application of this, care should be taken that $P_1 - P_2$ equal the arithmetical sum of the total changes in P. By successive approximation we readily obtain values of c, for each group given above, and the mean of the two values for each mean anomaly is then taken.

For the displacements in the plane of the ecliptic, let

β_1 be the true anomaly in the earth's orbit of the planet's projected radius vector;

β, the earth's true anomaly.

c_2, the linear displacement in the ecliptic;

δ, the angle which c_2 makes with the planet's projected radius vector;

ρ, the planet's radius vector;

λ, the planet's latitude;

R, the earth's radius vector:

Then
$$r^2 = R^2 - 2R\rho\cos\lambda\cos(\beta-\beta_1) + \rho^2\cos^2\lambda$$
$$P = R\sin(\beta-(\beta_1+\delta)) - \rho\cos\lambda\sin\delta$$
$$-z = R\cos(\beta-(\beta_1+\delta)) - \rho\cos\lambda\cos\delta$$

and our fundamental equation takes the form

$$\gamma\tan 1'' = \frac{c_2\,(R\sin(\beta-(\beta_1+\delta)) - \rho\cos\lambda\sin\delta}{R^2 - 2R\rho\cos\lambda\cos(\beta-\beta_1) + \rho^2\cos^2\lambda + c\rho\cos\lambda\cos\delta - Rc\cos(\beta-(\beta_1+\delta))}$$

the mean of which, with regard to β, we have found for each group, by expanding with regard to β, supplying the numerical values of those quantities which depend upon the dimensions of the earth's orbit, and making successive approximations when necessary, we obtain by wholly elementary processes for each mean value of the displacement in longitude an equation of the form

$$\gamma_0\tan 1''(\tan\tfrac{1}{2}\beta_1 - \tan\tfrac{1}{2}\beta_2) = c_2(Aa(1-\varepsilon^2)\sin(\beta_1+\delta) + \varepsilon\rho\cos\lambda\sin\delta) + Ba(1-\varepsilon^2)\cos(\beta_1+\delta) + C\rho\cos\lambda\sin\delta)$$

when A, B and C are numerical values, a the major semi-axis, and ε the eccentricity of the earth's orbit. Expanding this with regard to β, and replacing those terms depending upon the value of the elements of the earth's orbit by their numerical values, and uniting the two equations for each value of the true anomaly, we obtain finally, from the errors in longitude, an equation of the form

$$c_2 = \frac{\gamma_0\tan 1''(\tan\frac{1}{2}\beta_2 - \tan\frac{1}{2}\beta_1)}{D\cos\delta + E\sin\delta}$$

Returning now to the displacements in latitude, we have the condition that the locus of the projected position of the displaced planet is parallel to the line of intersection of the planes of the two orbits; or that this locus crosses the projected radius at an angle ω. We also have, as will readily be seen, the point of intersection from the calculated planet's projected position equal to $c_1\cot\lambda$; and since c_2 must join this locus with the projected position of the calculated planet, we have

$$c_2 = \frac{c_1\cot\lambda\sin\omega}{\cos(90^\circ \pm (\omega-\delta))} = \frac{c_1\cot\lambda}{\pm\cos\delta + \cot\omega\sin\delta}$$

Equating with the equation obtained from longitudes, we have at once values for c_2 and δ, from which the values of δv and δr, the ecliptic values of the displacement in true anomaly and radius vector at once follow. These are tabulated as follows:

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CORRECTIONS TO BE APPLIED TO THE ECLIPTIC POSITION OF *Mercury*, AS CALCULATED BY LEVERRIER'S SECOND TABLE, TO OBTAIN THE POSITION GIVEN BY MERIDIAN OBSERVATIONS.

v	δv	δr
°	″	
15	—1.8097	—0.0000048
45	+2.2303	—0.0000052
75	+3.8814	—0.0000134
105	+1.4329	—0.0000070
135	+3.3773	—0.0000100
165	+6.0296	+0.0000446
195	+2.4717	—0.0000022
225	+0.3836	—0.0000002
255	—1.2062	+0.0000391
285	+1.3905	—0.0000008
315	+1.5319	—0.0000012
345	—3.9753	—0.0000005
Mean	+1.3948″	+0.0000031

The number of observations referred to LEVERRIER's first table is so small that it has seemed desirable to combine the results for each quadrant. The values are as follows:

CORRECTIONS TO BE ADDED TO THE ECLIPTIC POSITION OF *Mercury*, AS DEDUCED FROM LEVERRIER'S FIRST TABLE, TO OBTAIN ITS POSITION YIELDED BY MERIDIAN OBSERVATIONS.

v	δv	δr
45°	+10.083	—0.0000603
135	+10.755	+0.0000084
225	+ 9.807	+0.0000153
315	+ 6.779	+0.0000928
Mean	+9.3560″	+0.0000141

The corrections to the first table refer to the date 1872.3; those to the second refer to 1871.13.

It will be seen that each table contains a fairly regular variation about a constant term. On account of an uncertainty as to the date from which the corrections to the first table should be counted, we are constrained to employ the constant term and variation of the second table, using the results of the first table only for general corroboration.

The mean value of dv indicates an increment of the movement of *Mercury's* perihelion by 0″.0660, making it +44″.20 for a century, a value slightly higher than that given by NEWCOMB, +42″.95, which depended upon a different series of observations. The constant term of dv, depending upon the single extremely large value at 255°, has not seemed real.

Finally we present the periodic variation in orbit.

v	δv LeVerrier's 2d Table.		δv 1st Table.	δr
°	″	″	″	
15	—2.204			—0.0000048
45	+0.836	+0.381	+0.727	—0.0000052
75	+2.487			—0.0000134
105	+0.034			—0.0000078
135	+1.982	+2.217	+1.399	—0.0000100
165	+4.635			+0.0000446
195	+1.107			—0.0000022
225	—0.112	—0.445	+0.247	—0.0000002
255	—2.401			+0.0000398
285	—0.004			—0.0000008
315	+0.137	—1.746	—2.587	—0.0000012
345	—5.370			—0.0000005

It will be seen that the planet receives, when between 330° and 360° of true anomaly, a disturbance whose immediate effect is a considerable disturbance of its orbital velocity, so that the planet passes through perihelion later than was expected. The secondary effect appears to be to draw the planet nearer the sun, and increase its orbital velocity; so that the planet passes beyond its calculated place near aphelion, passes its aphelion slightly before the calculated position, and suffers a secondary effect of a similar character in passing from aphelion towards perihelion.

Although this action is such as to suggest a strong opinion as to its cause, I beg to delay the discussion thereof till I shall present certain relations which are found to exist among the elements of ENCKE's comet.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 a,

MADE AT THE DUDLEY OBSERVATORY,

BY LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Apr. 6 16 49 42	4	14, 14	+0 0.92	—1 26.4	22 19 9.56	+ 9 12 55.2	n9.605	0.738
" 18 15 47 25	5	15, 5	—3 9.01	—1 53.2	22 53 14.28	19 12 5.1	n9.654	0.717
" 28 16 9 14	6	9, 3	—0 51.33	+5 52.2	23 19 9.27	25 39 54.6	n9.655	0.643
May 2 15 8 47	7	15, 5	+2 32.73	+4 27.5	23 28 42.20	27 51 25.1	n9.688	0.692
" 13 15 10 37	8	18, 6	—0 41.36	+0 46.9	23 53 5.04	33 6 45.8	n9.705	0.630
" 21 15 32 40	9	15, 5	—5 1.45	—0 3.7	0 8 52.84	+36 20 13.3	n9.701	0.532

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Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
4	22 19 9.56	—0.93	+ 9 12 55.2	— 8.1	[Bessel], [Lamont] and Grant
5	22 56 24.09	0.80	19 14 8.3	10.0	Lal. and Comp. with DM.+ 19° 5027
6	23 20 1.27	0.67	25 34 13.4	11.0	Bessel Zone 321 (Weisse 377)
7	23 26 10.05	0.58	27 51 25.1	11.2	Weisse 524 and Rümker 11292
8	23 53 46.84	0.44	33 6 10.8	11.9	Struve 2861 and Leiden A.G. Zones.
9	0 13 54.56	—0.27	+36 20 28.7	—11.7	Weisse's Bessel 319

For these observations the position-angle of the tail was nearly 270°; and this circumstance, together with an apparent actual elongation of the central condensation of the head of the comet, seems to favor the existence of considerable systematic errors in the observed right-ascensions. I intended always to observe the following and brightest part of the central condensation.

A proper motion of —0ˢ.008 and —0″.11 was applied in deducing the place of star No. 8, using the two observations of Lalande to aid in determining this quantity. The star is double, and the mean was observed.

To obtain a more reliable position of No. 5, I also measured its difference from Weisse's Bessel 1356. But the latter appears to be affected with a proper motion of about +0ˢ.02; +0″.1; and as there is no published position of this star at my disposition later than Weisse's, the comparison could not be used.

May 21. The appearance of the comet is transformed. Hitherto, the tail has been narrow and very bright along the axis; and the head has been small and elongated in the direction of the tail. Now, however, the tail has become broad and faint, and of uniform brightness across its breadth. There appears to be a bright outstreaming from the head in the direction ($p = 90°$) at right angles to the axis of the tail. These wings are perhaps 20″ in breadth, and 40″ in length on each side of the nucleus, and convex toward the following side (away from the tail). The boundary and contrast in brightness between the head and tail is very strongly marked. The nucleus is very much brighter than I have seen it during the month preceding. It is fully a quarter of a magnitude brighter than Lal. 330 (the comparison-star), and is decidedly star-like, with an intense light. The tail could not be traced beyond 15′ from the head. The general appearance of the head is that of a nearly rectangular nebulous mass of bright light about 90″ long and 20″ broad, with a star-like nucleus (of magnitude 7.0) just preceding the center.

OBSERVATIONS OF SAPPHO (80),

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6–INCH EQUATORIAL,

By Prof. E. FRISBY.

[Communicated by the Superintendent.]

1888 Washington M.T.	*	No. Comp.	(80) — * R.A.	(80) — * Dec.	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	s	″
April 3 11 17 15.4	17	20 , 4	+0 49.64	+4 39.3	n9.205	0.839
4 11 26 7.9	14	20 , 4	+3 20.83	—2 27.4	n9.125	0.777
7 10 37 28.2	16	20 , 4	—2 9.93	+3 41.7	n9.299	0.779
14 10 50 7.8	10	20 , 4	+1 55.53	—6 0.5	n9.033	0.749
" 10 50 7.8	11	20 , 4	—2 38.83	+1 56.5		
19 10 13 45.2	8	10 , 2	+0 40.08	+3 34.0	n9.118	0.827

The numbers of the comparison-stars refer to Bryant's list, *M.N. Astr. Soc.* Vol. XLIII, No. 3.

Positions of Comparison-Stars of 1888.0.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
17	13 27 26.12	+1.27	—13 40 13.5	—5.2	Weisse, Santini
14	24 0.46	1.28	13 25 21.0	5.1.	Weisse, Santini, Lamont
16	25 47	1.30	13 8.6	5.2	DM. —12° 3834
10	16 12.96	1.32	11 59 32.0	5.4	Gould, Paris 1870
11	20 48.35	1.32	12 7 27.8	5.4	Gould, Yarnall, (*i Virginis*)
8	12 56.35	+1.33	—11 25 30.0	—6.4	Weisse, Santini

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EPHEMERIS OF COMET 1888 *a* (SAWERTHAL),

CONTINUED FROM No. 171, BY LEWIS BOSS.

The following ephemeris of comet 1888 *a* is calculated from the elliptic elements in No. 171 of the *Astronomical Journal*. From an observation of May 21, at 20^h Greenwich mean time, the correction of the ephemeris on that date was $-2^s.2$ and $-8''$, and is very slowly increasing. Taking the brightness at discovery as the unit, the brightness on June 15 will be 0.059; on July 15, 0.029; and on Aug. 14, 0.019. The positions are for Greenwich 12^h of the corresponding dates.

1888	App. α	App. δ	log r	log Δ
	h m s	° ′ ″		
June 15.5	0 46 47.5	+44 9 1	0.24921	0.30240
16.5	0 48 2.9	44 25 3		
17.5	0 49 6.6	44 40 53	0.25607	0.30524
18.5	0 50 13.5	44 56 31		
19.5	0 51 18.6	45 11 59	0.26281	0.30784
20.5	0 52 21.8	45 27 16		
21.5	0 53 23.2	45 42 23	0.26942	0.31036
22.5	0 54 22.8	45 57 19		
23.5	0 55 20.5	46 12 4	0.27591	0.31275
24.5	0 56 16.3	46 26 40		
25.5	0 57 10.2	46 41 6	0.28229	0.31501
26.5	0 58 2.1	46 55 22		
27.5	0 58 52.1	47 9 28	0.28856	0.31715
28.5	0 59 40.2	47 23 24		
29.5	1 0 26.2	47 37 10	0.29472	0.31918
30.5	1 1 10.2	47 50 47		
July 1.5	1 1 52.2	48 4 15	0.30077	0.32109
2.5	1 2 32.1	48 17 33		
3.5	1 3 10.0	48 30 42	0.30672	0.32290
4.5	1 3 45.7	48 43 42		
5.5	1 4 19.3	48 56 32	0.31257	0.32459
6.5	1 4 50.7	49 9 12		
7.5	1 5 20.0	49 21 43	0.31832	0.32619
8.5	1 5 47.0	49 34 4		
9.5	1 6 11.9	49 46 16	0.32398	0.32770
10.5	1 6 34.4	49 58 18		
July 11.5	1 6 54.7	50 10 9	0.32955	0.32911
12.5	1 7 12.7	50 21 51		
13.5	1 7 28.4	50 33 23	0.33503	0.33044
14.5	1 7 41.8	50 44 45		
15.5	1 7 52.8	50 55 57	0.34043	0.33169
16.5	1 8 1.5	51 6 58		
17.5	1 8 7.8	51 17 48	0.34574	0.33287
18.5	1 8 11.7	51 28 28		
19.5	1 8 13.2	51 38 57	0.35097	0.33398
20.5	1 8 12.2	51 49 15		
21.5	1 8 8.9	51 59 21	0.35612	0.33503
22.5	1 8 3.0	52 9 16		
23.5	1 7 54.7	52 19 0	0.36119	0.33602
24.5	1 7 44.0	52 28 32		
25.5	1 7 30.7	52 37 52	0.36619	0.33696
26.5	1 7 14.9	52 47 0		
27.5	1 6 56.6	52 55 55	0.37111	0.33785
28.5	1 6 35.7	53 4 37		
29.5	1 6 12.3	53 13 7	0.37597	0.33870
30.5	1 5 46.4	53 21 23		
31.5	1 5 17.9	53 29 25	0.38075	0.33952
Aug. 1.5	1 4 46.9	53 37 13		
2.5	1 4 13.3	53 44 47	0.38547	0.34030
3.5	1 3 37.2	53 52 6		
4.5	1 2 58.5	53 59 10	0.39012	0.34107
5.5	1 2 17.2	54 5 59		
6.5	1 1 33.5	54 12 31	0.39471	0.34182
7.5	1 0 47.2	54 18 47		
8.5	0 59 58.4	54 24 47	0.39923	0.34256
9.5	0 59 7.2	54 30 29		
10.5	0 58 13.5	54 35 53	0.40369	0.34330
11.5	0 57 17.5	54 41 0		
12.5	0 56 19.1	54 45 49	0.40810	0.34405
13.5	0 55 18.4	54 50 19		
14.5	0 54 15.4	54 54 31	0.41244	0.34480

OBSERVATION OF COMET 1888 *a*,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

BY H. P. TUTTLE.

1888	Washington M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
May 20	d h m s 15 24 58.8	1	10, 2	+4 m 5.99 s	−2′ 42.4″	0 h 7 m 1.18 s	+35° 57′ 8.6″	n9.731	0.504

Mean Place of Comparison-Star for 1888.0.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	0 h 2 m 55.51 s	−0.32 s	+36° 0′ 33.4″	−12.4″	Weisse's Bessel XXIII, 477

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OBSERVED MAXIMA AND MINIMA OF *T* AND *U MONOCEROTIS*, 1888,

By PAUL S. YENDELL.

T Monocerotis. 2279

A series of thirty-seven observations of this star was obtained this year, extending from Feb. 15 to May 7. Three maxima and three minima are shown by these observations, as follows:

Observed Maxima. Cambridge M.T.		Observed Minima. Cambridge M.T.	
1888 February	19.2	1888 March	7.13
March	18.28	April	3.5
April	13.9	"	30.2

The above times were obtained by Pogson's method from a drawing of the light-curve shown by all the observations.

U Monocerotis. 2276

Forty-four observations of this star, beginning Feb. 6, and ending May 9, show the following times of maxima and minima:

Observed Maxima. Cambridge M.T.		Observed Minima. Cambridge M.T.	
1888 March	9.52	1888 February	28.2
April	29.74	April	9.36

These times were obtained in the same manner as were those of *T Monocerotis*, given above; and although both series were much interrupted by weather and moonlight, all the maxima and minima may be considered to be well-determined.

Dorchester, 1888 *May* 24.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *a*,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY WITH THE 10-INCH EQUATORIAL,

By Prof. F. P. LEAVENWORTH and H. V. GUMMERE.

1888 Haverford M.T.		*	No. Comp.	☄—* $\Delta\alpha$	☄—* $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
	d h m s			m s	′ ″	h m s	° ′ ″	s		
Mar. 29	16 55 6	1	9 , 1	+0 4.80	+5 54.5	21 54 48.72	+ 0 46 41.0	n9.621	0.750	L
"	16 55 6	2	9 , 2	+0 2.58	−0 12.7	21 54 48.67	0 46 44.4	n9.621	0.750	L
30	16 58 40	3	12 , 3	−3 1.63	+1 54.5	21 57 54.58	1 55 29.9	n9.617	0.745	L
Apr. 16	16 23 29	4	18	+0 28.24	–	22 47 51.30	–	n9.650	–	L
"	15 40 15	4	3	–	+ 7 21.2	–	17 43 23.5	–	0.704	L
23	16 5 48	5	6 , 2	+3 44.17	+12 4.0	23 6 32.00	22 37 16.7	n9.681	0.622	L
"	16 14 33	6	3 , 3	−1 13.62	− 6 5.2	23 6 33.21	22 37 36.8	n9.681	0.622	L
24	15 17 16	7	26 , 7	−0 48.31	− 1 9.0	23 9 1.59	23 14 15.1	n9.690	0.693	L
25	16 14 2	8	27 , 5	+1 30.58	+ 4 25.6	23 11 40.37	23 53 6.7	n9.666	0.624	G
26	16 1 48	9	24 , 3	+0 57.12	− 6 31.3	23 14 10.66	24 29 20.9	n9.631	0.631	L
"	16 9 22	10	9 , 4	−2 2.80	− 2 22.5	23 14 11.36	24 29 33.2	n9.631	0.631	L
"	16 5 35	11	12 , 2	−2 7.83	− 6 55.4	23 14 10.67	+24 29 25.6	n9.631	0.631	L

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 54 44.98	−1.06	+ 0 40 52.9	− 6.4	Harvard Stand. Cat. bet. 0° and +1°
2	21 54 47.15	1.06	0 47 3.5	6.4	Weisse's Bessel
3	22 0 57.26	1.05	1 53 42.0	6.6	¼(Lam. + Bonn + 2 Schjellerup)
4	22 47 23.86	0.80	17 36 12.0	9.7	Bonn Obs. VI + 17° 4822
5	23 2 48.55	0.72	22 25 23.3	10.6	Weisse's Bessell 1400
6	23 7 47.57	0.74	22 43 52.6	10.6	Bonn Obs. VI + 22° 4793
7	23 9 50.63	0.73	23 15 34.8	10.7	Weisse's Bessell 154
8	23 10 10.46	0.67	23 48 52.1	11.0	Weisse's Bessel 161
9	23 13 14.24	0.70	24 36 3.1	10.9	Weisse's Bessel 233
10	23 16 14.87	0.71	24 32 6.6	10.9	Weisse's Bessel 299
11	23 16 19.21	−0.71	+24 36 31.9	−10.9	½(Weisse's Bessel + Rümker)

March 30. Nucleus elongated, or perhaps double.

I am indebted to Prof. Edgar Frisby and Mr. Frank Muller, for positions of some of the star-places.

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NEW ASTEROID.

A planet of the twelfth magnitude was discovered May 16 by Palisa, at Vienna. Its position was

1888 May 16.5483 Gr. M.T. $\alpha = 245° 16' 56''$ $\delta = 21° 35' 12''$ Daily motion —56ˢ in α and 1′ southward.

This will be No. 279, should that found by Borrelly, May 12, prove not to be *Xantippe*.

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE,

By S. C. CHANDLER.

Approximate Greenwich M.T., 1888.

July

	d	h
U Coron. Bor.	1	13
U Ophiuchi	1	20
Algol	1	21
U Ophiuchi	2	16
U Ophiuchi	3	12
Y Cygni	3	17
Algol	4	18
U Cephei	5	10
δ Librae	5	14
Y Cygni	6	17
U Ophiuchi	6	21
Algol	7	15
U Ophiuchi	7	17
U Coron. Bor.	8	12
U Ophiuchi	8	13
U Ophiuchi	9	9
Y Cygni	9	17
U Cephei	10	10
Algol	10	12
δ Librae	12	14
Y Cygni	12	17
U Ophiuchi	12	18
Algol	13	9
U Ophiuchi	13	14
U Ophiuchi	14	10
λ Tauri	14	23
U Coron. Bor.	15	10
U Cephei	15	10
Y Cygni	15	17
U Ophiuchi	17	18
U Ophiuchi	18	15
Y Cygni	18	17
λ Tauri	18	22

July

	d	h
U Ophiuchi	19	11
δ Librae	19	14
U Cephei	20	9
Y Cygni	21	17
Algol	21	23
λ Tauri	22	21
U Ophiuchi	23	15
U Ophiuchi	24	12
Y Cygni	24	17
Algol	24	20
U Cephei	25	9
Librae	26	13
λ Tauri	26	20
Y Cygni	27	16
Algol	27	17
U Ophiuchi	28	16
U Ophiuchi	29	12
U Cephei	30	9
Algol	30	14
Y Cygni	30	16
λ Tauri	30	19

August

	d	h
U Coron. Bor.	1	16
Algol	2	10
δ Librae	2	13
Y Cygni	2	16
U Ophiuchi	2	17
U Ophiuchi	3	13
λ Tauri	3	17
U Ophiuchi	4	9
Y Cygni	5	16
λ Tauri	7	16

August

	d	h
U Ophiuchi	7	17
U Ophiuchi	8	14
U Coron. Bor.	8	14
Y Cygni	8	16
U Ophiuchi	9	10
δ Librae	9	12
λ Tauri	11	15
Y Cygni	11	16
U Ophiuchi	12	18
U Ophiuchi	13	15
U Ophiuchi	14	11
Y Cygni	14	16
U Coron. Bor.	15	11
λ Tauri	15	14
δ Librae	16	12
Algol	16	18
Y Cygni	17	16
U Ophiuchi	18	15
U Ophiuchi	19	11
λ Tauri	19	13
Algol	19	15
U Ophiuchi	20	8
Y Cygni	20	16
U Coron. Bor.	22	9
Algol	22	12
δ Librae	23	12
Y Cygni	23	16
U Ophiuchi	23	16
U Ophiuchi	24	12
U Ophiuchi	25	8
Algol	25	9
Y Cygni	26	16

August

	d	h
U Ophiuchi	29	13
Y Cygni	29	16
U Ophiuchi	30	9
δ Librae	30	11

September

	d	h
Y Cygni	1	16
Algol	2	23
U Ophiuchi	3	14
U Ophiuchi	4	10
Y Cygni	4	16
Algol	5	20
δ Librae	6	11
Y Cygni	7	16
U Ophiuchi	8	14
U Coron. Bor.	8	15
Algol	8	17
U Ophiuchi	9	11
Y Cygni	10	15
Algol	11	14
δ Librae	13	10
Y Cygni	13	15
U Ophiuchi	13	15
Algol	14	11
U Ophiuchi	14	11
U Coron. Bor.	15	13
Y Cygni	16	15
U Ophiuchi	19	12
Y Cygni	19	15
U Ophiuchi	20	8
δ Librae	20	10
U Coron. Bor.	22	11

September

	d	h
Y Cygni	22	15
U Ophiuchi	24	13
U Ophiuchi	25	9
Y Cygni	25	15
Algol	25	22
δ Librae	27	9
Y Cygni	28	15
Algol	28	19
U Coron. Bor.	29	8
U Ophiuchi	29	14
U Ophiuchi	30	10

October

	d	h
Y Cygni	1	15
Algol	1	15
U Coron. Bor.	2	19
Algol	4	12
Y Cygni	4	15
U Ophiuchi	5	11
U Cephei	5	16
U Ophiuchi	6	7
Algol	7	9
Y Cygni	7	15
U Coron. Bor.	9	17
Algol	10	6
U Ophiuchi	10	11
Y Cygni	10	15
U Cephei	10	16
U Ophiuchi	11	7
Y Cygni	13	15
λ Tauri	13	21
U Cephei	13	15

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THE

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ORBITS OF AEROLITES,

BY H. A. NEWTON.

At the recent meeting of the National Academy of Sciences, I presented certain conclusions, derived from a collation of the statements of the observers of those stonefalls which are represented by specimens now in our museums. I assumed, as already proved, a relation between the comets and the meteoroids of various kinds; so that we may, in general and as a first approximation, assign to the latter bodies, on approaching the earth, a velocity in their orbits about the sun not greater than that of a parabola, and not less than that of the comet of shortest period. This gives them velocities between 1.414 and 1.244; the earth's mean velocity being unity. For uniformity of reduction, however, I used the maximum velocity in my reductions. A smaller velocity would in general strengthen the argument for the conclusions arrived at.

For 116 stonefalls, I was able to obtain some statement indicating the direction through the air of the fireball, or else the direction from which the stones came. For single meteors the actual path is certainly very uncertain. But I feel considerable confidence in the conclusions derived from the statement of all the falls, when the results are collated. If the several statements, when single, are accepted as correct, and if the most probable direction of the meteor be deduced when more than a single observation is reported, and if the velocity be assumed to be that belonging to a parabolic orbit, then it is found that 109 of the 116 bodies were moving about the sun in orbits having inclinations less than 90°, against 7 moving in orbits inclined more than 90°. For 94 other stonefalls only the time of day is given, with no indication of the direction of the meteor's motion. These cases, so far as they give any evidence, confirm the conclusions obtained from the 116 stonefalls before considered.

Again, treating individually the 116 paths, it appears that if we change the paths each through 180° of azimuth, the altitudes remaining unchanged, the point from which the meteor is moving will be thus carried away from the point from which the earth is moving in 70 cases, while the two points will approach each other in 44 cases. This implies that the reason why stones following the earth have been secured in so much larger numbers than those meeting the earth is not due entirely, or even mainly, to the times of day at which men from their habits of living, and of being out of doors, are likely to secure the stones. Either fewer stones come into the air, meeting the earth in its motion, or else such stones are in general destroyed in coming through the air by reason of their large velocities. But large velocities are not always fatal to the integrity of these bodies, and it seems more reasonable to believe that there are many more stones actually following the earth in its orbit about the sun than there are meeting the earth. Hence these bodies seem to have closer relations with the periodic comets than with comets of long period.

Another fact of interest is obtained by this discussion. Of the 116 orbits obtained as above, 103 have perihelion-distances greater than 0.5. With this may be compared some results from SCHIAPARELLI's table of orbits corresponding to 189 radiants of shooting stars observed by ZEZIOLI (**Entwurf einer Theorie der Sternschnuppen*, pp. 84–93, Stettin, 1871). In these orbits, 18 perihelion-distances were less than 0.5, against 169 greater than 0.5.

Yale University, 1888 *June* 12.

SOME OBSERVATIONS OF VARIABLE STARS IN 1887,

BY EDWIN F. SAWYER.

1. *R Virginis.*

This star was observed from May 12 to July 13, the observations numbering 13. When first seen, on May 12, *R* was = DM. 8°,2626, or about $8^{\mathrm{M}}.5$. The increase of light was rapid and uniform, a maximum being passed about June 17. Maximum brightness 3 steps > DM. 8°,2619, and 5 steps <

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DM. 9°,2648, or $7^{M}.1$. The decrease was not well observed, a gap occurring in the observations from June 27 to July 13. When last seen, on July 13, *R* was 1 step < DM. 8°,2626, or about $8^{M}.6$.

2. *R Coronae Borealis.*

Observed from March 20 to November 18, 22 observations being obtained. On March 20, the date of the first observation, *R* was found to be 5 steps > DM. 31°,2771, and 3 steps < DM. 30°,2682, or $6^{M}.8$. The light steadily decreased from this time until April 13, when it was = DM. 28°,2475, or about $7^{M}.4$. The star had apparently reached minimum, as the light remained constant from April 13 to May 23. On May 25, however, *R* was found still fainter, and on June 13, it was 5 + steps < DM. 28°,2475, or about $8^{M}.0$. On June 25, *R* was invisible in the field-glass, hence < $9^{M}.0$; and it was not again seen until October 17, when it was observed 5 steps > DM. 28°,2469, and 5 + steps < DM. 28°,2475, or $7^{M}.7$. The light increased very slowly, and when last seen, on November 18, *R* was 5 steps > DM. 28°,2475, and 1 or 2 steps < DM. 31°,2771, or $7^{M}.1$.

3. *S Coronae Borealis.*

13 observations were obtained on this star, extending from March 20 to June 13. When first seen, on March 20, *S* was 1 step > DM. 32°,2577, and 3 steps < DM. 32°,2578, or $8^{M}.0$. The light increased very rapid and rather irregularly, a maximum being passed on April 19. Maximum brightness, ½ step < DM. 31°,2719, and 5 + steps > DM. 32°,2578, or $7^{M}.1$. The decrease appeared rapid and uniform; and when last observed, on June 13, *S* was 4 steps < DM. 32°,2577, or about $8^{M}.5$.

4. *R Scuti.*

A very good series of observations on this star, 51 in number, was obtained, extending from May 23 to December 5. When first seen, on May 23, *R* was found quite bright, and evidently near maximum; light = 19.9 of my scale. The light remained constant until June 8, when it slowly decreased, and had apparently reached a standstill on August 7, remaining constant until August 25. Then it very suddenly decreased, and passed a faint minimum on September 14; light = 7.7. The brightness as rapidly increased; and a bright maximum was reached on October 27; light = 21.9. *R* remained at maximum for 14 days, then again very rapidly faded, and passed a bright minimum on November 23; light = 14.2. The interval between the two minima was 70 days.

5. *g Herculis.*

The fluctuations in light of this star, during the year, have been of a decided character, although very irregular. The observations number 41, and extend from March 25 to December 13. When first seen, on March 25, *g* was found quite bright (evidently near maximum); light = 16.1 of my scale. The light remained almost stationary (decreasing but two steps) until May 12, when a further slight, but sudden depression of 2 steps occurred, followed by a standstill until June 7, at which date another sudden fall of. two steps occurred, and a minimum was passed on June 9; light = 9.8. After a rapid and regular rise, a faint maximum was passed on July 4; light = 14.6. The light remained nearly constant from June 27 to July 19, when it rapidly decreased, and a faint minimum was reached on August 10; light = 8.4. The star remained faint for only a few days, when it again rapidly brightened, and a maximum was reached on September 23; light = 20.2. Another rapid fall of six steps occurred from October 5 to 17, followed by a standstill until November 21, and a rapid rise until the observations terminated on December 13. The last minimum, a rather bright one, was passed on November 4; light = 12.9. The interval between the two maxima was 81 days; the interval between the 1st and 2d minima, 62 days; and between the 2d and 3d minima, 86 days.

6. *R Canis Majoris.*

Owing to the low southern declination of this *Algol*-star, and from the fact that conveniently observed minima only occur at intervals of 7 or 8 days, it has been possible to secure but one good determination of minimum, which occurred on the evening of 1888 February 6. According to the mean of equal lights, a minimum was passed at $8^{h}\ 35^{m}.5$, Cambridge M.T. Duration of observation $3^{h}\ 26^{m}$.

7. *o Ceti.*

Observed from 1886 October 2 to 1887 February 19, 32 observations being obtained. When first seen, October 2, *o* was = SDM. —3°,362, or about $9^{M}.2$. The increase of light was rapid and generally uniform. A maximum was reached 1886 December 30. Maximum brightness, 5 steps > 308 (*U.A.*) *Ceti*, and 2 steps < 295 (*U.A.*) *Ceti*, or $4^{M}.4$. The decrease was not well observed, there being a serious break in the observations, extending from November 28 to December 14. When last observed, on February 19, *o* was 1 or 2 steps > 234 (*U.A.*) *Ceti*, and 5 + steps < 224 (*U.A.*) *Ceti*, or $6^{M}.5$.

8. 36 (*U.A.*) *Ceti.*

22 observations of this star were obtained, extending from 1887 September 10 to 1888 January 16. When first seen, on September 10, the star was 2 steps > 10 (*U.A.*) *Ceti*, and 1 step < 7 (*U.A.*) *Ceti*, or $6^{M}.0$. The increase of light was rapid and rather irregular. A maximum was passed December 3, the maximum brightness being 3 or 4 steps > 7 (*U.A.*) *Ceti*, and 3 or 4 steps < 18 (*U.A.*) *Ceti*, or $5^{M}.6$.

The light remained constant from October 12 to November 18, or 37 days. The decrease appeared quite rapid and irregular, and when last seen, on January 17, it was 1 step > 28 (*U.A.*) *Ceti*, and 3 steps < 10 (*U.A.*) *Ceti*, or $6^{M}.5$. The light remained at a standstill from January 2 until the observations terminated.

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9. *W Cygni.*

$21^h\ 30^m\ 33^s.9$, $+44°\ 43'.7$ (1855.0).

This star was under observation from 1887 May 23 to 1888 February 22, 57 observations being obtained. These observations, when charted, exhibit four well determined maxima and minima. When first seen, on May 23, *W* was 1 or 2 steps > DM. 44°,3889, and 5+ steps < DM. 46°,3305, or $6^M.4$, and had evidently just passed a maximum. The decrease of light appeared rapid and generally regular. A minimum was passed on July 23, the brightness being = DM. 43°,4002, or about $6^M.7$. The rise to maximum, from August 7, was very rapid and uniform, this place being reached on September 13; maximum brightness, 3 or 4 steps > DM. 44°,3889, and 2 steps < DM. 46°,3305, or $6^M.1$. After a rather rapid and very irregular fall of light, a second and bright minimum was passed on December 8, the brightness being 1 step > DM. 43°,4002, and 3 or 4 steps < DM. 44°,3889, or $6^M.7$. The second maximum (after a rapid rise) was reached 1888 January 29, the brightness being 2 or 3 steps > DM. 44,3889, and 3 steps < DM. 46°,3305, or $6^M.2$. The intervals between the maxima and minima were the same, or 138 days. The decrease, from February 9 until the observations terminated, appeared very slow.

10. *ρ Persei.*

Observed from 1887 September 10 to 1888 April 6, 26 observations. Serious breaks occur in the series, notably from September 17 to October 12, from October 19 to November 5, and from February 9 to 29. The observations, when charted, indicate two minima; the first about October 17, and the second about February 25. These determinations are very uncertain, however, and are probably several days in error.

11. *β Persei.*

Two minima of this star were obtained during the year. The times have been determined by Schönfeld's method, given on page 93 of the 36th *Jahresbericht des Mannheimer Vereins für Naturkunde.* The times by each comparison-star, and their means being as follows:

Comp. Star	Camb. M.T. of Min.	d	h	m	Weight
δ Persei,	1887 December	5	9	11.1	30
ε Persei,			9	3.8	27
α Trianguli,			9	10.3	16
Mean,	1887 December	5	9	8.2	73
ε Persei,	1888 February	9	7	57.2	30
δ Persei,			8	0.3	35
α Trianguli,			8	13.2	12
ρ Persei			7	57.3	15
Mean,	1888 February	9	8	0.5	92

12. *R Lyrae.*

Although 30 observations were obtained on this star, extending from June 27 to December 6, so many gaps occur at critical points of the light-curve, that it has only been possible to determine the times of three maxima, with any degree of certainty. These were September 9, October 15, and November 29, the last maximum being a bright one. A minimum occurred about November 10.

13. *ε Aurigae.*

Observed occasionally from 1887 October 12 to 1888 March 4, 19 observations. The light has remained nearly constant, fluctuating not more than two or three steps; but no decided phases have been observed.

14. *T Monocerotis.*

The observations on this star number 63, and extend from 1887 November 9 to 1888 April 16. From these, and using the mean light-curve formed from the 1881–83 observations, the following epochs of maxima and minima have been determined:

Observed Maxima		d	h	m	Observed Minima		d	h	m
1887	Nov.	29	16	50	1887	Nov.	20	2	18
	Dec.	27	10	53		Dec.	20	7	16
1888	Jan.	23	9	55	1888	Jan.	14	19	10
	Feb.	20	10	0		Feb.	9	9	31
	Mar.	17	12	2		Mar.	6	8	48
	Apr.	13	23	51		Apr.	4	3	3

LETTER FROM PROF. HOLDEN,

Director of the Lick Observatory.

The Lick Observatory, which was built under the direction of the Lick Trustees (Capt. R. S. Floyd, President, Thomas E. Fraser, Superintendent of Construction), is at last complete, and has been this day transferred to the Regents of the University of California.

All obstacles, some inevitable and some avoidable, have been surmounted. This has required knowledge, skill, patience, time and money; but it is done.

The instruments are all in place, and ready for work, including the great equatorial.

All the important object-glasses in the Observatory have been made by Alvan Clark & Sons, and have been pronounced to be satisfactory by competent judges, Professors Newcomb and Young among the rest.

The mounting for the large telescope was made by Warner and Swasey of Cleveland. It has likewise been inspected by competent judges (Prof. Newcomb and Mr. Burnham among others), and pronounced to be satisfactory in every respect.

The moving parts of the 75-foot dome were built by the Union Iron Works of San Francisco, and this part of the dome is also a complete success. The dome can be revolved 360° in nine minutes.

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The elevating floor invented by Sir HOWARD GRUBB was first adopted here. It is 61 feet in diameter, and has been easily raised 16½ feet in 9 minutes by 4 hydraulic rams in our experimental tests. The rams have but just been completed. All our preliminary trials indicate that this part of the work also will be entirely successful.

The Observatory begins its active existence to-night. The astronomers are, EDWARD S. HOLDEN, S. W. BURNHAM, J. M. SCHAEBERLE, J. E. KEELER, E. E. BARNARD, C. B. HILL. The work already done by these gentlemen is a guarantee that the instruments will not be idle.

Lick Observatory, San José, California, 1888 *June* 1.

The Observatory was founded to promote scientific research. It also receives special students of the University of California, of which it is a part. Visitors are likewise admitted during office hours every day, and on Saturday nights (only) from 7 to 10.

The Regents of the University of California have provided for the future of the Observatory liberally and intelligently.

Mr. LICK's original idea is now fully embodied in a practical form. The results of astronomical observations made here will make his name remembered forever.

EDWARD S. HOLDEN.

DEFINITIVE DETERMINATION OF THE ORBIT OF COMET 1887 IV,

BY FRANK MULLER.

This comet was discovered by Mr. E. E. BARNARD at the observatory of Vanderbilt University, Nashville, Tenn., on May 12. It was then 0′.5 in diameter, with a stellar nucleus of the 11-12 magnitude; about perihelion it was of the 9-10 magnitude, with a tail 2′ long; soon after it became diffuse and elongated in the direction north and south, and was last seen by Mr. BARNARD on August 11, when its theoretical relative brightness was 0.3.

1. *Preliminary elements, perturbations, and ephemeris.* — Several sets of elements were published, not resting however upon sufficient data to indicate any deviation from a parabolic path. Finally, Mr. CHANDLER (*Astronomical Journal*, No. 160) noted that the observations could not be satisfied by parabolic elements. From normal places for May 14, June 12, and July 12, he computed the following elements, which represent the observations closely, and are practic[illegible] definitive:

$$T = \text{June } 16.66108 \text{ Greenwich M.T.}$$

$$\left.\begin{aligned} \omega &= 15^\circ\ 8'\ 3''.7 \\ \Omega &= 245\ \ 13\ \ 16\ .8 \\ i &= 17\ \ 32\ \ 53\ .4 \end{aligned}\right\} 1887.0$$

$$\log q = 0.1441634$$

$$\log a = 2.5009248$$

$$e = 0.9956014$$

Upon these elements I have based the ephemeris for the preparation of the normal places. That the differences between the ephemeris and observation might contain only the errors of observation, the perturbations were computed and applied to the ephemeris. All the planets from *Mercury* to *Saturn* were considered; the disturbances were small, and were chiefly caused by *Jupiter*, and by the *Earth*, with which the comet was nearly in conjunction during the whole apparition. The perturbations of the rectangular ecli[illegible] coordinates were computed for every eight days, an[illegible] corresponding changes in right-ascension and decli[illegible] were as follows:

1887 Gr. M.T.	Δx	Δy	Δz	$\Delta\alpha$ ″	$\Delta\delta$ ″
May 10.0	—242	—73	— 5	—6.44	[illegible]
18.0	167	49	6	5.17	[illegible]
26.0	—106	—31	— 5	—3.72	[illegible]
June 3.0	— 59	—17	— 3	—2.27	+0.14
11.0	26	8	2	1.06	—0.08
19.0	7	2	1	0.27	0.05
27.0	0	0	0	0.00	0.00
July 5.0	6	2	1	0.25	0.07
13.0	25	9	2	0.94	0.27
21.0	57	20	5	1.96	0.56
29.0	99	36	9	3.17	0.89
Aug. 6.0	153	57	15	[illegible]	1.21
14.0	[illegible]	—84	—21	[illegible]	—1.52

To avoid i[illegible]g any irregularit[illegible]nterpolation of the ephem[illegible] and $\Delta\delta$ were s[illegible] obtained for every day. [illegible]es and places o[illegible]rbing plan[illegible] were taken f[illegible] Berlin *Jahrbuc[illegible]*

The reduc[illegible]pparent place[illegible]ated, by [illegible] of the indep[illegible]tar-numbers [illegible]*erican* [illegible] *Almanac*, fo[illegible]four days. [illegible]olation [illegible]ection also [illegible]ned for ev[illegible]

These cor[illegible]ing appl[illegible]wing [illegible]g ephemer[illegible]eenwich [illegible] an[illegible]h day:

1887

[illegible]

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1887		α h m s	δ ° ′ ″	log Δ
May	22.0	15 26 36.12	—25 6 2.5	9.6363
	22.5	27 31.08	24 45 46.6	
	23.0	28 26.44	24 25 16.8	9.6324
	23.5	29 22.20	24 4 33.5	
	24.0	30 18.36	23 43 37.0	9.6287
	24.5	31 14.90	23 22 27.7	
	25.0	32 11.84	23 1 5.9	9.6252
	25.5	33 9.17	22 39 32.1	
	26.0	34 6.88	22 17 46.7	9.6219
	26.5	35 5.00	21 55 50.1	
	27.0	36 3.48	21 33 42.8	9.6189
	27.5	37 2.35	21 11 25.2	
	28.0	38 1.58	20 48 57.8	9.6161
	28.5	39 1.17	20 26 21.1	
	29.0	40 1.12	20 3 35.6	9.6134
	29.5	41 1.43	19 40 41.8	
	30.0	42 2.08	19 17 40.2	9.6111
	30.5	43 3.08	18 54 31.3	
	31.0	44 4.41	18 31 15.8	9.6090
	31.5	45 6.07	18 7 54.2	
June	1.0	46 8.04	17 44 27.0	9.6071
	1.5	47 10.34	17 20 54.8	
	2.0	48 12.93	16 57 18.2	9.6055
	2.5	49 15.82	16 33 37.8	
	3.0	50 19.00	16 9 54.2	9.6041
	3.5	51 22.47	15 46 8.0	
	4.0	52 26.20	15 22 19.8	9.6030
	4.5	53 30.20	14 58 30.1	
	5.0	54 34.46	14 34 39.7	9.6021
	5.5	55 38.95	13 10 49.1	
	6.0	56 43.67	13 46 59.0	9.6015
	6.5	57 48.62	13 23 9.9	
	7.0	58 53.78	12 59 22.4	9.6011
	7.5	15 59 59.15	12 35 37.3	
	8.0	16 1 4.71	12 11 55.0	9.6010
	8.5	2 10.46	11 48 16.3	
	9.0	3 16.39	11 24 41.6	9.6012
	9.5	4 22.48	11 1 11.6	
	10.0	5 28.74	10 37 47.0	9.6016
	10.5	6 35.14	10 14 28.2	
	11.0	7 41.68	9 51 15.8	9.6023
	11.5	8 48.35	9 28 10.5	
	12.0	9 55.15	9 5 12.8	9.6032
	12.5	11 2.06	8 42 23.2	
	13.0	12 9.08	8 19 42.3	9.6043
	13.5	13 16.20	7 57 10.5	
	14.0	14 23.43	7 34 48.5	9.6057
	14.5	15 30.73	7 12 36.7	
	15.0	16 38.12	6 50 35.5	9.6074
	15.5	17 45.58	6 28 45.6	
	16.0	18 53.12	6 7 7.2	9.6092
	16.5	20 0.71	5 45 40.9	
	17.0	21 8.35	5 24 27.0	9.6113
	17.5	22 16.04	5 3 26.1	
	18.0	23 23.78	4 42 38.5	9.6136
	18.5	24 31.54	4 22 4.6	
	19.0	25 39.34	4 1 44.7	9.6161
	19.5	26 47.15	3 41 39.2	
	20.0	27 54.98	3 21 48.3	9.6188
	20.5	29 2.82	3 2 12.5	
	21.0	30 10.67	2 42 51.9	9.6217
	21.5	31 18.52	2 23 46.9	
	22.0	32 26.37	2 4 57.6	9.6249
	22.5	16 33 34.20	— 1 46 24.4	
June	23.0	16 34 42.03	—1 28 7.3	9.6281
	23.5	35 49.83	1 10 6.6	
	24.0	36 57.61	0 52 22.6	9.6316
	24.5	38 5.35	0 34 55.2	
	25.0	39 13.06	0 17 44.6	9.6352
	25.5	40 20.74	—0 0 51.1	
	26.0	41 28.36	+0 15 45.4	9.6389
	26.5	42 35.93	0 32 4.6	
	27.0	43 43.45	0 48 6.7	9.6428
	27.5	44 50.91	1 3 51.4	
	28.0	45 58.30	1 19 18.8	9.6469
	28.5	47 5.62	1 34 28.8	
	29.0	48 12.87	1 49 21.4	9.6511
	29.5	49 20.03	2 3 56.6	
	30.0	50 27.12	2 18 14.3	9.6554
	30.5	51 34.11	2 32 14.7	
July	1.0	52 41.01	2 45 57.8	9.6598
	1.5	53 47.81	2 59 23.5	
	2.0	54 54.51	3 12 32.0	9.6644
	2.5	56 1.10	3 25 23.2	
	3.0	57 7.58	3 37 57.3	9.6690
	3.5	58 13.94	3 50 14.4	
	4.0	16 59 20.18	4 2 14.4	9.6738
	4.5	17 0 26.31	4 13 57.6	
	5.0	1 32.30	4 25 24.0	9.6786
	5.5	2 38.16	4 36 33.7	
	6.0	3 43.89	4 47 26.9	9.6835
	6.5	4 49.49	4 58 3.5	
	7.0	5 54.94	5 8 23.9	9.6885
	7.5	7 0.26	5 18 28.0	
	8.0	8 5.43	5 28 16.1	9.6936
	8.5	9 10.45	5 37 48.3	
	9.0	10 15.33	5 47 4.6	5.6987
	9.5	11 20.06	5 56 5.3	
	10.0	12 24.64	6 4 50.5	9.7039
	10.5	13 29.08	6 13 20.4	
	11.0	14 33.36	6 21 35.1	9.7092
	11.5	15 37.49	6 29 34.7	
	12.0	16 41.47	6 37 19.5	9.7145
	12.5	17 45.31	6 44 49.6	
	13.0	18 48.99	6 52 5.1	9.7199
	13.5	19 52.53	6 59 6.3	
	14.0	20 55.92	7 5 53.3	9.7254
	14.5	21 59.16	7 12 26.2	
	15.0	23 2.25	7 18 45.4	9.7308
	15.5	24 5.20	7 24 50.9	
	16.0	25 8.00	7 30 42.8	9.7363
	16.5	26 10.66	7 36 21.6	
	17.0	27 13.18	7 41 47.1	9.7418
	17.5	28 15.56	7 46 59.8	
	18.0	29 17.79	7 51 59.7	9.7473
	18.5	30 19.89	7 56 47.1	
	19.0	31 21.84	8 1 22.1	9.7530
	19.5	32 23.67	8 5 45.0	
	20.0	33 25.36	8 9 55.9	9.7586
	20.5	34 26.92	8 13 55.0	
	21.0	35 28.35	8 17 42.6	9.7643
	21.5	36 29.65	8 21 18.8	
	22.0	37 30.82	8 24 43.8	9.7700
	22.5	38 31.86	8 27 57.9	
	23.0	39 32.78	8 31 1.2	9.7757
	23.5	40 33.58	8 33 53.9	
	24.0	41 34.26	8 36 36.2	9.7814
	24.5	17 42 34.81	+8 39 8.3	

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EDWARD S. HOLDEN.

DEFINITIVE DETERMINATION OF THE ORBIT OF COMET 1887 IV,

BY FRANK MULLER.

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1. *Preliminary elements, perturbations, and ephemeris.* — Several sets of elements were published, not resting however upon sufficient data to indicate any deviation from a parabolic path. Finally, Mr. CHANDLER (*Astronomical Journal*, No. 160) noted that the observations could not be satisfied by parabolic elements. From normal places for May 14, June 12, and July 12, he computed the following elements, which represent the observations closely, and are practically definitive:

$$\begin{aligned} T &= \text{June } 16.66108 \text{ Greenwich M.T.} \\ \left.\begin{aligned} \omega &= 15^\circ\ 8'\ 3''.7 \\ \Omega &= 245\ \ 13\ \ 16\ .8 \\ i &= 17\ \ 32\ \ 53\ .4 \end{aligned}\right\} & 1887.0 \\ \log q &= 0.1441634 \\ \log a &= 2.5009248 \\ e &= 0.9956014 \end{aligned}$$

Upon these elements I have based the ephemeris for the preparation of the normal places. That the differences between the ephemeris and observation might contain only the errors of observation, the perturbations were computed and applied to the ephemeris. All the planets from *Mercury* to *Saturn* were considered; the disturbances were small, and were chiefly caused by *Jupiter*, and by the *Earth*, with which the comet was nearly in conjunction during the whole apparition. The perturbations of the rectangular ecliptic coordinates were computed for every eight days, and the corresponding changes in right-ascension and declination were as follows:

1887 Gr. M.T.		Δx	Δy	Δz	$\Delta\alpha$	$\Delta\delta$
					″	″
May	10.0	—242	—73	— 5	—6.44	+3.49
	18.0	167	49	6	5.17	1.98
	26.0	—106	—31	— 5	—3.72	+0.81
June	3.0	— 59	—17	— 3	—2.27	+0.14
	11.0	26	8	2	1.06	—0.08
	19.0	7	2	1	0.27	0.05
	27.0	0	0	0	0.00	0.00
July	5.0	6	2	1	0.25	0.07
	13.0	25	9	2	0.94	0.27
	21.0	57	20	5	1.96	0.56
	29.0	99	36	9	3.17	0.89
Aug.	6.0	153	57	15	4.48	1.21
	14.0	—216	—84	—21	—5.78	—1.52

To avoid introducing any irregularity in the interpolation of the ephemeris, $\Delta\alpha$ and $\Delta\delta$ were separately obtained for every day. The masses and places of the disturbing planets were taken from the Berlin *Jahrbuch*.

The reduction to apparent place was computed, by means of the independent star-numbers of the *American Nautical Almanac*, for every four days. By interpolation this correction also was obtained for every day.

These corrections being applied, the following is the resulting ephemeris for Greenwich mean noon and midnight of each day:

1887		α	δ	log Δ
		h m s	° ′ ″	
May	12.0	15 9 40.94	—30 56 47.5	9.6845
	12.5	10 27.95	30 41 52.6	
	13.0	11 15.34	30 26 40.8	9.6790
	13.5	12 3.12	30 11 11.9	
	14.0	12 51.30	29 55 26.1	9.6737
	14.5	13 39.86	29 39 23.4	
	15.0	14 28.82	29 23 3.7	9.6685
	15.5	15 18.18	29 6 27.3	
	16.0	16 7.94	28 49 34.2	9.6634
	16.5	16 58.09	28 32 24.4	
	17.0	17 48.64	28 14 58.0	9.6585
	17.5	18 39.58	27 57 15.3	
	18.0	19 30.93	27 39 16.4	9.6537
	18.5	20 22.67	27 21 1.3	
	19.0	21 14.82	27 2 30.3	9.6491
	19.5	22 7.36	26 43 43.7	
	20.0	23 0.30	26 24 41.5	9.6447
	20.5	23 53.66	25 5 24.0	
	21.0	24 47.41	25 45 51,5	9.6404
	21.5	15 25 41.56	—25 26 4.2	

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1887		α (h m s)	δ (° ′ ″)	log Δ
May	22.0	15 26 36.12	−25 6 2.5	9.6363
	22.5	27 31.08	24 45 46.6	
	23.0	28 26.44	24 25 16.8	9.6324
	23.5	29 22.20	24 4 33.5	
	24.0	30 18.36	23 43 37.0	9.6287
	24.5	31 14.90	23 22 27.7	
	25.0	32 11.84	23 1 5.9	9.6252
	25.5	33 9.17	22 39 32.1	
	26.0	34 6.88	22 17 46.7	9.6219
	26.5	35 5.00	21 55 50.1	
	27.0	36 3.48	21 33 42.8	9.6189
	27.5	37 2.35	21 11 25.2	
	28.0	38 1.58	20 48 57.8	9.6161
	28.5	39 1.17	20 26 21.1	
	29.0	40 1.12	20 3 35.6	9.6134
	29.5	41 1.43	19 40 41.8	
	30.0	42 2.08	19 17 40.2	9.6111
	30.5	43 3.08	18 54 31.3	
	31.0	44 4.41	18 31 15.8	9.6090
	31.5	45 6.07	18 7 54.2	
June	1.0	46 8.04	17 44 27.0	9.6071
	1.5	47 10.34	17 20 54.8	
	2.0	48 12.93	16 57 18.2	9.6055
	2.5	49 15.82	16 33 37.8	
	3.0	50 19.00	16 9 54.2	9.6041
	3.5	51 22.47	15 46 8.0	
	4.0	52 26.20	15 22 19.8	9.6030
	4.5	53 30.20	14 58 30.1	
	5.0	54 34.46	14 34 39.7	9.6021
	5.5	55 38.95	13 10 49.1	
	6.0	56 43.67	13 46 59.0	9.6015
	6.5	57 48.62	13 23 9.9	
	7.0	58 53.78	12 59 22.4	9.6011
	7.5	15 59 59.15	12 35 37.3	
	8.0	16 1 4.71	12 11 55.0	9.6010
	8.5	2 10.46	11 48 16.3	
	9.0	3 16.39	11 24 41.6	9.6012
	9.5	4 22.48	11 1 11.6	
	10.0	5 28.74	10 37 47.0	9.6016
	10.5	6 35.14	10 14 28.2	
	11.0	7 41.68	9 51 15.8	9.6023
	11.5	8 48.35	9 28 10.5	
	12.0	9 55.15	9 5 12.8	9.6032
	12.5	11 2.06	8 42 23.2	
	13.0	12 9.08	8 19 42.3	9.6043
	13.5	13 16.20	7 57 10.5	
	14.0	14 23.43	7 34 48.5	9.6057
	14.5	15 30.73	7 12 36.7	
	15.0	16 38.12	6 50 35.5	9.6074
	15.5	17 45.58	6 28 45.6	
	16.0	18 53.12	6 7 7.2	9.6092
	16.5	20 0.71	5 45 40.9	
	17.0	21 8.35	5 24 27.0	9.6113
	17.5	22 16.04	5 3 26.1	
	18.0	23 23.78	4 42 38.5	9.6136
	18.5	24 31.54	4 22 4.6	
	19.0	25 39.34	4 1 44.7	9.6161
	19.5	26 47.15	3 41 39.2	
	20.0	27 54.98	3 21 48.3	9.6188
	20.5	29 2.82	3 2 12.5	
	21.0	30 10.67	2 42 51.9	9.6217
	21.5	31 18.52	2 23 46.9	
	22.0	32 26.37	2 4 57.6	9.6249
	22.5	16 33 34.20	− 1 46 24.4	
June	23.0	16 34 42.03	−1 28 7.3	9.6281
	23.5	35 49.83	1 10 6.6	
	24.0	36 57.61	0 52 22.6	9.6316
	24.5	38 5.35	0 34 55.2	
	25.0	39 13.06	0 17 44.6	9.6352
	25.5	40 20.74	−0 0 51.1	
	26.0	41 28.36	+0 15 45.4	9.6389
	26.5	42 35.93	0 32 4.6	
	27.0	43 43.45	0 48 6.7	9.6428
	27.5	44 50.91	1 3 51.4	
	28.0	45 58.30	1 19 18.8	9.6469
	28.5	47 5.62	1 34 28.8	
	29.0	48 12.87	1 49 21.4	9.6511
	29.5	49 20.03	2 3 56.6	
	30.0	50 27.12	2 18 14.3	9.6554
	30.5	51 34.11	2 32 14.7	
July	1.0	52 41.01	2 45 57.8	9.6598
	1.5	53 47.81	2 59 23.5	
	2.0	54 54.51	3 12 32.0	9.6644
	2.5	56 1.10	3 25 23.2	
	3.0	57 7.58	3 37 57.3	9.6690
	3.5	58 13.94	3 50 14.4	
	4.0	16 59 20.18	4 2 14.4	9.6738
	4.5	17 0 26.31	4 13 57.6	
	5.0	1 32.30	4 25 24.0	9.6786
	5.5	2 38.16	4 36 33.7	
	6.0	3 43.89	4 47 26.9	9.6835
	6.5	4 49.49	4 58 3.5	
	7.0	5 54.94	5 8 23.9	9.6885
	7.5	7 0.26	5 18 28.0	
	8.0	8 5.43	5 28 16.1	9.6936
	8.5	9 10.45	5 37 48.3	
	9.0	10 15.33	5 47 4.6	5.6987
	9.5	11 20.06	5 56 5.3	
	10.0	12 24.64	6 4 50.5	9.7039
	10.5	13 29.08	6 13 20.4	
	11.0	14 33.36	6 21 35.1	9.7092
	11.5	15 37.49	6 29 34.7	
	12.0	16 41.47	6 37 19.5	9.7145
	12.5	17 45.31	6 44 49.6	
	13.0	18 48.99	6 52 5.1	9.7199
	13.5	19 52.53	6 59 6.3	
	14.0	20 55.92	7 5 53.3	9.7254
	14.5	21 59.16	7 12 26.2	
	15.0	23 2.25	7 18 45.4	9.7308
	15.5	24 5.20	7 24 50.9	
	16.0	25 8.00	7 30 42.8	9.7363
	16.5	26 10.66	7 36 21.6	
	17.0	27 13.18	7 41 47.1	9.7418
	17.5	28 15.56	7 46 59.8	
	18.0	29 17.79	7 51 59.7	9.7473
	18.5	30 19.89	7 56 47.1	
	19.0	31 21.84	8 1 22.1	9.7530
	19.5	32 23.67	8 5 45.0	
	20.0	33 25.36	8 9 55.9	9.7586
	20.5	34 26.92	8 13 55.0	
	21.0	35 28.35	8 17 42.6	9.7643
	21.5	36 29.65	8 21 18.8	
	22.0	37 30.82	8 24 43.8	9.7700
	22.5	38 31.86	8 27 57.9	
	23.0	39 32.78	8 31 1.2	9.7757
	23.5	40 33.58	8 33 53.9	
	24.0	41 34.26	8 36 36.2	9.7814
	24.5	17 42 34.81	+8 39 8.3	

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1887		α	δ	log Δ
		h m s	° ′ ″	
July	25.0	17 43 35.24	+8 41 30.4	9.7872
	25.5	44 35.56	8 43 42.8	
	26.0	45 35.76	8 45 45.4	9.7929
	26.5	46 35.84	8 47 38.7	
	27.0	47 35.81	8 49 22.7	9.7987
	27.5	48 35.66	8 50 57.7	
	28.0	49 35.40	8 52 23.8	9.8044
	28.5	50 35.02	8 53 41.2	
	29.0	51 34.52	8 54 50.0	9.8103
	29.5	52 33.92	8 55 50.6	
	30.0	53 33.19	8 56 43.0	9.8161
	30.5	54 32.36	8 57 27.4	
	31.0	55 31.41	8 58 4.0	9.8219
	31.5	56 30.35	8 58 33.0	
Aug.	1.0	57 29.18	8 58 54.4	9.8277
	1.5	58 27.89	8 59 8.6	
	2.0	17 59 26.50	8 59 15.7	9.8335
	2.5	18 0 25.00	8 59 15.8	
	3.0	1 23.38	8 59 9.0	9.8393
	3.5	2 21.66	8 58 55.6	
	4.0	3 19.83	8 58 35.7	9.8451
	4.5	4 17.90	8 58 9.4	
	5.0	5 15.86	8 57 36.8	9.8509
	5.5	6 13.71	8 56 58.2	
	6.0	7 11.46	8 56 13.6	9.8567
	6.5	8 9.11	8 55 23.3	
	7.0	9 6.65	8 54 27.3	9.8625
	7.5	10 4.10	8 53 25.8	
	8.0	11 1.44	8 52 18.9	9.8684
	8.5	11 58.70	8 51 6.8	
	9.0	12 55.85	8 49 49.5	9.8742
	9.5	13 52.90	8 48 27.3	
	10.0	14 49.87	8 47 0.2	9.8800
	10.5	15 46.74	8 45 28.5	
	11.0	16 43.52	8 43 52.1	9.8858
	11.5	17 40.21	8 42 11.2	
	12.0	18 18 36.82	+8 40 26.0	9.8916

Comparison of part of this ephemeris with an ephemeris computed by Mr. Chandler showed small differences, which Mr. Chandler explained by stating that in the reduction to apparent place he had used the *British Nautical Almanac*, in which nutation-terms of short period are neglected.

2. *Comparison-Stars.*—The stars used lie between 30° south declination, and 8° north declination. The positions of all stars brighter than the ninth magnitude, between —2° and +5°, have been kindly furnished by Prof. Kortazzi of Nicolajew, and Prof. Boss of Albany, from their as yet unpublished A.G. Zone observations. The positions of the stars north of +5° had not been reduced, but I am indebted to Prof. Bruns of Leipsic, for the apparent places of these stars. With a few exceptions, all the positions from the A.G. zones are the means of two or more observations. I am also indebted to Mr. Skinner of the U.S. Naval Observatory for places from various catalogues.

South of —2°, the southern limit of the *Astronomische Gesellschaft* zones, I have collected nearly all the observations of the stars used; this appears desirable for the detection of proper motion, and the elimination of accidental errors. While a complete discussion is not warranted, some system is necessary in combining these miscellaneous observations. The weights given below were assigned, taking into consideration the accuracy of observation and the chance of the effect of a proper motion too small to be detected. These weights were used when the places depended on one or two observations; for three to six observations the weights were increased by one-half; for seven or more observations they were doubled, the systematic error of the catalogues being then probably in excess of the accidental errors.

For the sake of brevity, I have given only the adopted mean place and the authorities upon which it rests. To indicate the various catalogues the following abbreviations are used:

A. = Oeltzen's Argelander. Weight $\frac{1}{4}$.

A.G. = *Astronomische Gesellschaft* zones. Abbreviations are attached to show the places of observations; Albany, Leipsic and Nicolajew. Weight $\frac{3}{4}$.

A N. = Star-places in *Astronomische Nachrichten*.

Ar. = Second Armagh Catalogue. Weight $\frac{1}{2}$.

B = Bonn Observations, Vol. VI. Weight $\frac{1}{4}$.

Br. = Brisbane, Observations at Paramatta. Weight $\frac{1}{8}$.

C, CZ = Argentine General or Zone Catalogue. Weight 1.

Cin. = Cincinnati Zone Catalogue. Weight $\frac{1}{2}$.

Cp. = Catalogues, for the epochs 1840, '50, '60, '80, of stars observed at the Cape of Good Hope. 1840–60, weight $\frac{1}{2}$; 1880, weight 1.

D. = Observations made at Dunsink, 1885. Weight 1.

G. = Göttingen. Weight $\frac{1}{2}$.

Gr. = Greenwich. Weight $\frac{1}{2}$.

L. = Lamont. Weight $\frac{1}{4}$.

P. = Pulkowa. Weight $\frac{1}{2}$.

R. = Radcliffe, 1884–85–86. Weight 1.

Si. = Santini. Weight $\frac{1}{4}$.

Sj. = Schjellerup. Weight $\frac{3}{8}$.

T. = Tacchini (Washburn Obs. publications). Weight $\frac{1}{4}$.

W.Z. = Washington Zones. Weight $\frac{1}{8}$.

Y. = Yarnall. Weight $\frac{1}{2}$.

Comp. indicates that the places were obtained by a comparison with a known star.

The Washington zones were only used when no other authority was available.

Mean Places for 1887.0 of the Comparison-Stars.

No.	α	δ	Authorities.	No.	α	δ	Authorities.
	h m s	° ′ ″			h m s	° ′ ″	
1	15 10 57.34	—29 43 55.8	A, C, Cp,'40,'50,'60,'80, Y	4	15 12 30.07	—28 33 37.8	A, C
2	11 3.17	30 3 38.6	A, CZ, Y	5	12 51.25	29 29 22.9	CZ
3	15 11 45.84	—30 47 40.8	A, C, Cp '40, '80	6	15 13 4.02	—29 41 39.4	A, CZ

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No.	α	δ	Authorities	No.	α	δ	Authorities
	h m s	° ′ ″			h m s	° ′ ″	
7	15 13 43.31	—27 52 33.5	A, B, C, Cp '80	63	16 8 4.18	—10 7 35.9	AN, W
8	14 34.31	29 7 8.1	CZ	64	8 20.70	10 22 21.8	W, Y
9	15 53.22	28 56 8.4	A, Br, Cp '80, CZ, Y	65	8 37.90	9 26 55.5	L, Sj
10	16 3.36	28 46 4.3	A, CZ	66	9 28.64	8 4 9.6	P, Sj
11	20 0.26	27 34 34.0	A, C, Y	67	11 48.66	7 7 10.4	W
12	21 20.73	26 44 23.5	C	68	11 51.75	8 0 12.7	W
13	21 22.80	27 13 55.5	CZ	69	12 44.00	8 47 32.7	Sj
14	21 32.51	26 43 27.7	C	70	13 6.45	6 35 51.1	W
15	21 44.37	26 38 0.3	CZ	71	16 7.66	7 21 35.2	Comp
16	21 58.42	26 7 11.4	CZ	72	16 25.24	6 35 47.2	W, Sj
17	22 40.42	26 12 48.1	A, CZ	73	16 55.00	6 56 30.7	LL
17^1	24 15.11	25 35 32.4	Comp	74	18 12.54	6 9 12.6	W
17^2	25 15.94	25 30 50.2	Comp	75	18 19.29	6 27 43.0	Harrow Mer Circle
18	26 23.39	25 24 56.5	A, C, Cp '80, WZ, Y	76	18 46.97	7 21 41.4	Sj, W
19	26 28.38	24 6 21.5	A, Cp '80, Y	77	18 54.40	5 47 29.7	Comp
20	27 12.20	24 43 40.3	A, Br, C, Cp '80 Gr '60, Y	78	19 28.79	5 50 9.6	L
21	28 23.36	24 43 31.1	A, C, Cp '80, Y	79	19 37.28	5 38 12.5	LL
22	29 27.78	24 14 42.3	Comp	80	19 48.78	5 50 9.5	L
23	29 54.76	28 37 8.1	B, C, T	81	20 17.93	4 25 6.1	Sj
24	30 8.12	24 12 40.3	CZ	82	22 48.21	5 11 38.2	Sj, W
25	30 32.14	23 16 37.0	A, AN, CZ	83	23 9.24	5 12 3.1	Sj, W
26	30 32.92	21 10 54.0	Paris Mer Circle	84	23 37.45	5 2 53.0	AN
27	30 36.63	24 2 3.4	A, CZ	85	23 59.41	2 27 52.3	Sj, W
28	30 55.03	21 45 34.1	C, D, Y	86	24 25.78	5 50 48.5	AN, Sj, W
29	32 6.17	22 40 40.5	A, C, T, Y	87	24 44.45	4 25 2.6	Comp
30	32 25.3	22 6 12.1	WZ	88	26 13.57	3 43 20.5	Comp
31	32 42.54	22 46 46.2	A, AN, C, Y	88^1	26 16.50	4 15 12.7	Sj
32	32 51.00	23 25 50.6	C	88^2	27 38.61	3 8 29.8	Comp
33	32 57.90	23 21 13.9	C	89	28 1.92	3 33 3.1	AN, L
34	33 5.74	22 31 22.0	Y	90	28 28.62	3 46 36.4	L
35	33 36.09	23 26 59.1	C, Cp 40, '50, '60, '80, Gr '72. R	91	29 58.47	2 57 29.2	Comp
36	33 44.76	22 7 5.6	Comp	92	30 25.09	2 4 56.1	C, D
37	34 8.62	21 14 11.5	B	93	31 7.00	2 26 3.4	Sj
38	35 13.61	22 54 25.2	A, B, C, T	94	31 26.36	2 48 51.0	Sj, W
39	35 15.68	23 56 7.1	A, C, LL, WZ	95	32 26.17	2 12 10.0	Sj, W
40	36 45.10	20 45 14.3	A, WZ	96	32 42.68	1 49 54.7	L
41	37 42.07	22 1 4.0	A, WZ	97	32 43.52	1 0 16.3	G
42	38 5.40	21 9 39.6	Comp	98	32 50.92	0 57 29.0	AG Nic
43	40 28.87	18 46 48.8	A	99	34 35.87	1 37 10.3	AG Nic
44	40 47.39	20 6 50.4	AN, B, Cin	100	34 58.26	1 46 39.8	Sj, W
45	41 18.93	21 17 6.7	Paris Mer Circle	101	35 55.54	1 55 36.5	AG Nic
46	42 7.82	18 52 0.6	A	102	36 6.27	0 28 36.4	W
47	43 5.51	20 25 50.6	A, AN, B, Cin	103	36 36.15	1 14 51.2	Comp
48	45 7.86	18 35 44.9	A, Y	104	36 41.57	— 1 53 56.6	AG Nic
49	45 47.33	18 5 46.8	A	105	37 42.62	+ 0 8 40.1	B
49^1	46 46.47	19 47 41.9	C, Y	106	37 52.94	— 0 34 14.6	G, L
50	48 28.55	19 2 53.3	A, CZ, R, Y	107	37 56.65	1 23 46.2	B
51	56 13.19	13 29 47.6	B	108	38 26.09	0 1 4.7	Comp
52	15 58 9.28	11 3 36.0	AN, C, R, Sj, W, Y	109	39 1.00	0 7 43.4	AG Nic
53	16 0 46.38	11 59 40.5	Gr '40, W	110	39 56.96	— 0 33 16.6	AG Nic
54	1 2.65	12 49 46.0	Sj	111	41 34.73	+ 0 0 14.3	L
55	1 19.87	12 26 25.9	C, R	112	43 40.53	1 5 24.7	L
56	1 30.49	11 36 50.8	W	113	44 3.13	2 6 38.5	AG Alb
57	3 6.14	11 15 4.6	Comp	114	44 52.55	0 30 56.0	B
58	3 6.59	12 4 31.9	AN, Sj, W	115	45 30.02	1 35 9.7	AG Alb
59	3 38.09	10 49 57.6	Si, W	116	45 40.97	1 24 33.1	$\frac{1}{3}$ (2 Gl+Sj)
59^1	4 38.89	11 46 13.2	Sj	117	47 40.13	1 32 10.4	AG Alb
59^2	5 18.22	10 58 4.5	Comp	118	48 26.83	2 2 28.6	L
59^3	5 45.18	10 19 41.3	B	119	50 22.22	1 36 7.4	AG Alb
60	5 49.49	9 46 13.3	AN, Sj, W	120	51 30.66	3 20 21.5	AG Alb
61	6 7.69	10 54 26.0	Si, W	121	52 19.85	2 31 2.3	W
62	16 7 35.11	—10 17 13.4	W	122	16 54 5.56	+2 31 3.7	AG Alb

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No.	α	δ	Authorities	No.	α	δ	Authorities
	h m s	° ′ ″			h m s	° ′ ″	
123	16 58 57.16	+2 55 27.4	AG Alb	145[1]	17 25 8.04	+6 51 3.0	B
124	17 4 30.38	5 2 48.3	AG Leip	146	26 36.76	7 36 0.6	AG Leip
125	5 7.35	5 31 19.2	"	147	28 4.41	7 15 29.3	"
126	7 2.80	5 2 43.4	"	148	28 27.14	8 11 5.0	"
127	7 18.84	6 11 1.4	"	149	34 29.64	7 51 50.0	"
128	8 11.42	5 56 32.6	"	150	35 12.11	8 32 10.7	"
129	8 47.07	5 35 2.0	Comp	151	36 25.76	8 16 31.4	"
130	10 55.07	5 15 15.5	AG Leip	152	37 32.46	8 6 49.8	½ (W+LL)
131	11 21.54	5 58 23.9	Comp	153	38 6.16	8 29 15.4	B
132	13 21.41	6 12 17.2	AG Leip	154	38 20.62	8 39 59.5	AG Leip
133	14 18.38	6 40 4.2	"	155	42 8.30	8 35 22.7	"
134	15 18.14	6 32 59.1	"	156	45 39.37	8 33 41.9	"
135	15 21.47	6 48 24.4	"	157	47 29.06	8 50 7.2	B
136	15 54.89	6 32 35.2	L, W	158	47 30.14	8 43 5.4	B
137	16 48.80	6 46 8.7	AG Leip	159	17 49 59.13	8 55 15.5	A.G. Leip
138	17 50.19	6 43 46.0	Comp	160	18 8 29.90	8 56 44.1	W
139	17 54.30	7 11 59.9	B	161	8 55.59	8 51 4.3	A.G. Leip
140	18 55.62	6 37 26.7	AG Leip	162	9 30.02	8 56 43.1	"
141	19 44.46	6 31 54.8	"	163	9 45.65	8 45 20.4	Sj, W
142	20 2.40	6 45 49.0	"	164	12 41.25	8 47 39.4	Comp
143	20 51.72	7 41 42.6	"	165	15 36.34	8 34 40.9	A.G. Leip
144	23 4.19	7 21 45.7	"	166	18 17 17.22	+8 43 45.4	"
145	17 24 8.62	+7 36 36.2	"				

REMARKS.

3. The Cape Catalogue of 1880 gives a proper motion of +0s.010 deduced from comparison with the Catalogue of 1840, but the other observations do not sustain the determination.

7. A provisional proper motion of —0″.08 in δ was used.

18. Prof. Kortazzi used a proper motion for this star and the preceding one determined by comparison with Lacaille; Lacaille not being available I have used a provisional proper motion of +0s.010 in α.

20. The S.P.D. of Brisbane 5382 requires a correction of —5′.

28. The declination of Yarnall 6425 is incorrect. Prof. Frisby has kindly given the correct declination for 1860, —21° 39′ 9″.6.

29. Lalande not being available, a provisional proper motion of +0s.005 in α was used.

39. Prof. Boss gives the proper motion as —0s.009 and —0″.50 (*A.J.* 157).

44. A proper motion, given in the Cincinnati Zone Catalogue, of —0s.0075 and —0″.111 was used.

55. There appears to be a small negative proper motion in right ascension.

66. The proper motion of +0s.0112 and —0″514, given in the Pulkowa Catalogue, was used.

92. The right-ascensions given in LL, W, L, Sj, C, D, and A.G. Nic. are well satisfied with a proper motion of +0s.028. The declinations are very discordant but are best satisfied with a proper motion of —0″.09.

3. *Observations of the Comet.* — On collecting all the observations published, 313 were found available. The right-ascensions and declinations given below are the observed values corrected for parallax and for the adopted places of the comparison-stars; Δα and Δδ are the differences (O—C) between these values and the values given by the ephemeris. The observations are arranged alphabetically with reference to the place of observation. The name of the observer, the aperture of the instrument used, and the place of the publication of the observations, are given. In many cases the character of the instrument used was not stated; in these cases it has been assumed in accordance with the known equipment of the observatory in question. *R.* denotes that a ring-micrometer, and *Mer.* that a meridian circle, was used, in other cases a filar-micrometer was employed.

Gr. M.T.	α	δ	Δα	Δδ	*
Albany. Boss. 13 in. *A.J.* 157.					
May	h m s	° ′ ″	s	′	
13.67719	15 12 20.43	—30 5 44.0	+0.28	— 5.3	2
15.71082	15 38.40	28 59 26.3	(—0.71	4.1)	9
18.72316	20 46.43	27 12 52.6	+0.54	— 5.2	13
23.71682	29 46.85	23 55 30.0	+0.35	+ 0.2	27
23.75353	15 29 50.83	—23 53 58.9	+0.21	— 0.9	38
May 15. Observation doubtful.					
Algiers. Rambaud. 50 cm. *A.N.* 2788; *B.A.* Oct., Nov.					
May					
16.46698	15 16 55.30	—28 33 44.5	+0.53	—11.6	10
18.39274	15 20 12.44	—27 25 5.3	+0.81	— 7.8	11

Gr.M.T.	α	δ	Δα	Δδ	*
Algiers. Rambaud. *A.N.* 2788; *B.A.* Oct., Nov.					
May	h m s	° ′ ″	s	″	
19.44698	15 22 2.87	—26 45 47.4	+1.11	— 3.5	14
20.37656	23 40.76	26 10 19.6	0.31	— 8.5	17
21.36892	25 27.82	25 31 16.7	.49	+ 0.1	18
23.37552	29 9.03	24 9 50.2	.74	— 8.0	24
24.37556	31 0.84	23 27 51.0	.05	6.2	23
25.41920	33 0.70	22 43 4.6	.83	2.6	37
26.40731	34 54.24	22 0 0.7	+0.06	5.7	40
28.40828	15 38 50.08	—20 30 36.3	—0.16	— 6.3	39

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Gr. M.T.	α	δ	Δα	Δδ	*
Algiers. Rambaud. *A.N.* 2788; *B.A.* Oct., Nov.					
Aug.	h m s	° ′ ″	s	″	
8.39656	18 11 46.86	+ 8 51 26.9	0.00	+ 4.8	163
9.35318	18 13 35.23	+ 8 48 46.2	(—0.93	— 5.8)	164
May 16–24. Signs of parallax-factors for α changed.					
May 26. Sign of Δδ changed.					
Algiers. Trépied. 50 cm. *A.N.* 2788; *B.A.*, Oct., Nov.					
May 16.42894	15 16 51.62	—28 35 11.2	(—0.78	—19.5)	10
18.36561	20 9.27	27 26 10.4	+0.56	13.0	11
19.41858	21 59.46	26 46 56.2	.68	8.0	14
20.36493	22 39.54	26 10 41.2	.34	3.1	17
21.36002	25 26.97	25 31 44.0	.61	5.9	18
23.35992	29 7.13	24 10 30.6	.59	7.4	24
24.36413	30 59.67	23 28 23.5	0.17	9.6	23
25.40290	32 59.30	22 44 52.0	1.30	7.7	37
28.32227	15 38 47.12	—20 31 48.5	+0.01	— 7.2	39
Aug. 8.37098	18 11 43.76	+ 8 51 18.2	—0.18	— 7.7	163
9.36638	18 13 36.69	+ 7 48 41.9	(—0.98	— 7.9)	164
May 16–24. Signs of parallax-factors for δ changed.					
Algiers. Sy. 50 cm. *B.A.*, Nov.					
Aug. 9.38796	18 13 39.17	+ 8 48 37.5	(—0.96	— 8.7)	164
Berlin. Battermann. 6f refr. *A.N.* 2808.					
June 16.45728	16 19 55.47	— 5 47 44.1	+0.54	—13.8	80
24.47733	38 4.18	— 0 35 24.9	(1.90	+17.4)	106
26.43876	16 42 29.45	+ 0 29 55.0	+1.79	—10.6	114
Berlin. Knorre. 9 in.? *A.N.* 2787, 2826.					
May 23.45273	15 29 17.47	—24 6 36.8	+0.56	— 5.2	27
June 24.43564	16 37 56.84	— 0 37 16.6	+0.20	— 7.6	106
Besançon. Gruey. 8 in. *C.R.* XV. 13.					
June 13.46540	16 13 12.26	— 7 59 6.1	+0.30	—22.3	68
14.47580	15 28.70	7 13 37.1	1.23	+ 3.8	71
16.45435	19 54.78	5 47 42.6	0.25	— 4.8	80
16.49858	20 0.65	5 46 0.7	.14	16.2	80
17.41889	16 22 5.88	— 5 6 57.6	+0.82	— 7.8	83
July 8.39210	17 8 56.88	+ 5 35 51.2	+0.45	+ 6.2	129
8.41500	8 59.42	5 36 15.4	.01	+ 4.1	129
12.40788	17 34.08	6 43 21.7	.52	—17.7	140
12.48854	17 44.27	6 44 30.9	.43	17.6	140
16.41407	26 0.08	7 35 23.9	+ .17	0.4	146
23.46638	17 40 28.71	+ 8 33 35.9	—0.79	— 6.7	155
July 16. Δ N.P.D. incorrectly added.					
Besançon. Guillin. 7 in. Mer. *C.R.* XV. 13.					
June 17.42450	16 22 5.77	— 5 6 30.6	+0.05	+ 5.1	—
18.42332	24 20.87	4 25 32.6	.28	—19.7	—
20.42102	28 51.81	3 5 40.9	.30	23.7	—
21.41984	31 7.50	2 27 13.1	+ .14	—23.9	—
22.41866	16 33 23.30	— 1 48 57.1	(—0.13	+27.3)	—
Besançon. Herique. 8 in. *C.R.* XV. 13.					
June	h m s	° ′ ″	s	″	
18.45995	16 24 26.64	— 4 23 52.6	+0.53	— 9.7	88[1]
20.44311	28 55.35	3 4 39.8	.25	—15.3	91
21.50811	31 20.45	2 23 28.2	.83	+ 0.2	95
22.45071	33 28.32	1 48 21.9	.80	— 8.5	100
23.47095	35 46.57	1 11 18.2	.68	9.0	103
24.42892	16 37 56.13	— 0 37 30.9	+0.41	— 7.9	110
July 16.45592	17 26 5.88	+ 7 35 47.2	+0.74	— 5.0	146
July 16. Δ N.P.D. incorrectly added.					
Bordeaux. Courty. 14 in. *A.N.* 2793.					
May 27.40909	15 36 52.24	—21 15 31.7	0.00	— 2.5	37
June 9.41395	16 4 11.65	—11 5 21.0	+0.55	— 7.1	52
10.42858	6 26.09	10 17 46.6	.45	+ 1.1	64
16.39597	19 46.89	5 50 16.1	+ .25	— 8.6	86
17.40344	22 2.26	5 7 32.1	— .71	3.5	82
17.40344	22 3.81	5 7 43.9	+ .84	15.3	84
21.40736	16 31 6.25	— 2 27 26.8	+0.30	— 8.9	85
Bordeaux. Flamme. 14 in. *A.N.* 2793, 2803.					
May 27.47768	15 37 0.26	—21 12 26.0	+0.55	— 0.8	37
June 13.44806	16 13 9.46	— 7 59 32.4	+0.23	— 1.9	66
28.49344	16 47 5.20	— 1 34 6.2	+0.46	—10.8	119
July 1.56054	16 58 56.30	— 3 0 59.2	+0.41	— 0.7	123
12.51014	17 17 46.89	6 45 2.9	.29	+ 4.4	133
22.47940	38 29.84	8 27 45.5	.49	— 4.6	150
27.48267	48 33.79	50 57.1	.20	+ 2.6	159
29.45557	17 52 28.80	— 55 53.9	+0.16	+ 8.4	159
Aug. 6.43196	18 7 1.49	— 55 41.7	+0.22	+11.2	160
8.42611	11 50.37	51 20.6	.13	2.8	161
10.43007	18 15 39.04	+ 8 45 49.2	+0.25	+ 7.6	166
July 29. Sign of Δ N.P.D. changed.					
Bordeaux. Rayet. 14 in. *A.N.* 2793, 2803.					
May 22.42317	15 27 23.52	—24 49 4.0	+0.91	— 9.7	20
26.41277	15 34 56.54	—21 59 51.1	+1.72	—10.5	30
June 11.44261	16 8 40.77	— 9 32 6.9	(+0.08	—77.7)	65
12.40966	10 50.25	8 46 30.9	+ .29	0.9	69
14.43718	15 22.22	7 15 39.8	— .05	—16.4	67
15.42183	17 35.68	6 32 8.5	+ .65	+ 0.9	70
18.43440	24 23.04	4 24 51.4	+ .39	— 5.7	81
22.43296	33 24.70	1 49 8.2	— .41	15.5	104
29.46876	49 16.36	— 2 2 53.0	+ .52	9.4	113
30.42517	16 51 24.52	+ 2 30 2.0	+0.43	— 8.1	122
July 2.46214	16 55 56.48	+ 3 24 27.4	+0.42	+ 2.0	120
6.43414	17 4 47.14	4 57 23.6	.28	(43.0)	126
7.41786	6 49.86	5 16 50.5	.32	0.6	130
11.42414	15 28.16	6 28 28.1	.39	5.2	141
13.42092	19 40.19	6 58 10.6	.70	10.0	135
19.44571	32 17.45	8 5 19.1	.49	2.1	148
24.41942	17 42 25.30	+ 8 38 56.1	+0.24	+11.6	156
July 2. δ changed 10′.					
July 7. α changed 1^m.					

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Bothkamp. J. LAMP. 30 cm? *A.N.* 2792, 2797.

Gr. M.T.	α	δ	Δα	Δδ	*
	h m s	° ′ ″	s	″	
June 15.46852	16 17 42.19	— 6 30 11.4	+0.85	— 2.7	72
16.45355	19 55.82	5 48 53.6	.39	13.8	86
24.48831	38 4.53	— 0 35 29.1	.76	9.6	110
28.48334	16 47 3.62	+ 1 33 54.2	+0.24	— 4.6	117
July 25.43843	17 44 27.65	+ 8 43 28.5	+0.11	+ 2.8	158
25.45595	17 44 30.37	+ 8 43 32.6	+0.12	+ 1.1	158

Cambridge, Mass. CHANDLER. 6.5 in. *A.J.* 163.

Gr. M.T.	α	δ	Δα	Δδ	*
May 30.63543	15 43 20.46	—18 48 22.4	+0.80	— 8.4	46
30.65337	43 22.19	47 23.6	.33	+ 0.4	43
30.66104	15 43 22.90	—18 47 9.9	+0.10	— 7.4	48
July 12.58900	17 17 56.59	+ 6 46 1.8	—0.06	— 6.4	137
12.61558	17 18 1.18	+ 6 46 31.8	+1.14	+ 0.3	142

Cambridge, Mass. WENDELL. 15 in. *A.N.* 2799.

Gr. M.T.	α	δ	Δα	Δδ	*
May 13.63818	15 12 16.26	—30 7 4.1	+0.44	— 2.4	2
14.63784	13 53.50	29 34 59.8	+ .28	3.8	5
19.66315	22 24.49	26 37 35.6	— .10	3.0	14
25.63713	33 25.23	22 33 36.3	+ .27	1.0	29
30.60634	15 43 15.89	—18 49 37.3	—0.21	— 2.2	46
June 7.60177	16 0 12.47	—12 30 53.5	—0.01	— 7.0	55
8.59124	2 23.15	11 43 55.9	+ .67	+ 1.9	62
13.69348	13 42.35	7 48 32.2	+ .15	—12.2	68
14.69343	15 45.10	7 7 52.7	— .46	7.9	73
15.60010	17 58.95	— 6 24 25.8	0.15	1.2	72
25.64926	16 40 39.69	+ 0 3 39.9	(—1.23	—28.3)	105

Cape of Good Hope. FINLAY. 7 in. *A.N.* 2805.

Gr. M.T.	α	δ	Δα	Δδ	*
May 19.56766	15 22 15.01	—26 40 14.9	+0.51	— 4.9	12
21.28890	25 29.50	25 34 32.8	(9.85	5.5)	17[1]
21.29450	25 30.10		(10.84)		17[2]
23.24944	28 54.54	24 15 3.2	0.33	5.0	22
24.27179	30 49.43	23 32 13.8	+0.39	5.2	23
27.60281	15 37 12.37	—21 7 1.1	(—2.13	—12.2)	42
June 8.21528	16 1 33.66	—12 1 55.9	+0.66	—13.3	53
9.23044	3 47.22	11 13 57.2	.39	6.1	57
17.50669	16 22 17.86	— 5 3 18.4	+0.91	— 9.0	84

Signs of parallax-factors for *a* changed.
Right-ascensions given half weight; declinations, double weight.

Dresden. ENGELHARDT. 30 cm. *A.N.* 2786, 2788, 2792, 2797

Gr. M.T.	α	δ	Δα	Δδ	*
May 19.44089	15 22 2.56	—26 45 46.4	+1.43	+11.2	12
22.42624	15 27 23.86	—24 48 50.9	+0.91	— 4.1	21
June 13.42811	16 13 7.00	— 8 0 48.5	+0.45	—24.2	66
July 16.41721	17 26 0.29	+ 7 35 24.6	—0.01	— 1.8	145

Geneva. KAMMERMANN. 10 in. *A.N.* 2823.

Gr. M.T.	α	δ	Δα	Δδ	*
May 19.41078	15 21 58.26	—26 47 5.4	+0.31	+ 0.4	12
June 6.38892	15 57 34.81	—13 28 31.0	+0.64	— 3.8	51
10.40752	16 6 23.33	10 18 52.0	.49	— 5.6	59[3]
12.38933	10 47.46	8 47 24.9	.22	+ 0.7	69
13.38213	13 1.07	8 2 35.6	0.70	— 7.3	68
14.41456	19 15 20.40	— 7 16 28.4	+1.17	— 4.9	71

Geneva. KAMMERMANN. 10 in. *A.N.* 2823.

Gr. M.T.	α	δ	Δα	Δδ	*
	h m s	° ′ ″	s	″	
June 15.40781	16 17 33.50	— 6 32 51.7	+0.36	— 5.5	72
16.40743	19 48.56	5 49 48.8	.37	10.7	78
17.41032	22 3.96	5 7 17.0	.06	5.7	82
21.40737	31 6.51	2 27 35.9	.56	18.0	93
24.38109	37 49.49	— 0 39 5.5	.25	2.7	106
27.39468	44 36.77	+ 1 0 25.2	+ .07	8.6	112
29.39141	49 5.26	2 0 45.4	— .19	2.6	118
30.39161	51 20.13	2 29 7.0	+ .53	7.0	121
30.41103	16 51 23.19	+ 2 29 40.4	+0.99	— 6.0	121

June 7–9, 19, 23. No accurate places of the comparison-stars could be obtained.

Gohlis. WINKLER. 6 in. R. *A.N.* 2797.

Gr. M.T.	α	δ	Δα	Δδ	*
June 13.46839	16 13 13.21	— 7 58 22.6	+1.25	+13.1	66
14.45962	15 26.40	7 14 39.1	1.11	—15.3	76
16.48353	19 58.73	5 46 51.4	0.25	(28.4)	86
17.46409	22 11.99	5 5 17.4	.81	21.1	84
18.47932	24 29.60	4 22 56.7	.86	1.2	88[1]
19.45156	26 40.91	3 43 45.8	.33	10.5	89
22.43750	33 26.52	1 48 51.6	.80	19.0	100
22.46461	33 30.19	1 47 51.4	.79	— 8.8	99
25.46974	40 17.40	0 1 46.9	.76	+ 5.3	109
25.49381	16 40 20.41	— 0 1 18.6	+0.51	—15.0	111

Göttingen. CLEMENS. 6 in. R? *A.N.* 2792.

Gr. M.T.	α	δ	Δα	Δδ	*
June 15.46252	16 17 42.40	— 6 30 38.8	—0.13	—15.5	70
16.46674	19 57.02	5 47 27.4	+0.81	21.3	74
17.43164	22 6.96	5 6 33.3	0.17	—15.5	82
17.50755	22 18.74	5 2 55.2	(1.68	+12.0)	84
22.46764	16 33 31.08	— 1 47 43.6	+1.27	— 7.7	96

June 22. Condensation following the center.
Right-ascensions given half weight.

Greenwich. TURNER. 6.7 in. *A.N.* 2797.

Gr. M.T.	α	δ	Δα	Δδ	*
June 12.50075	16 11 2.35	— 8 42 17.1	+0.29	+ 8.1	69
19.46981	26 44.16	3 43 10.4	1.10	—18.9	89
19.47455	16 26 43.84	— 3 42 50.3	+0.14	—10.1	90

June 12. DOWNING, observer.
June 18. Two observations by HOLLIS. No places for the comparison-stars.

Hamburg. LUTHER. 26 cm. *A.N.* 2792.

Gr. M.T.	α	δ	Δα	Δδ	*
June 16.48924	16 19 59.11	— 5 46 8.3	—0.14	+ 0.1	77
17.44567	22 8.33	5 5 43.0	—0.35	— 0.5	82
19.47826	16 26 44.26	— 3 42 31.1	+0.06	+ 0.2	90

Harrow. TUPMAN. 18 in. reflector R. *M.N.* 47.

Gr. M.T.	α	δ	Δα	Δδ	*
June 12.48266	16 11 0.03	— 8 43 17.9	+0.29	— 6.3	69
15.48574	17 44.21		.55		72
15.48574		6 29 35.5		12.8	75
17.49193	22 15.20	5 3 52.4	.25	6.0	82
19.47256	26 43.94	3 42 51.7	.51	— 6.7	89
22.45988	16 33 29.12	— 1 47 51.6	+0.33	+ 1.5	96

June 19. Time of observation changed 30^m. Declinations given half weight.

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Kiel. E. Lamp. 22 cm. *A.N.* 2786, 2787.

Gr. M.T.	α	δ	Δα	Δδ	*
	h m s	° ′ ″	s	″	
May 14.46069	15 13 37.04	−29 40 41.9	+0.98	− 2.2	1
16.46411	16 54.99	28 33 34.5	.52	+ 4.3	4
21.46071	15 25 37.84	−25 27 48.7	+0.90	− 3.9	18

Kremsmünster. Schwab. 15 cm? R. *A.N.* 2815.

Gr. M.T.	α	δ	Δα	Δδ	*
May 15.42241	15 15 11.70	−29 9 8.0	+1.21	− 5.0	8
26.42883	15 34 58.81	−21 58 58.7	(2.11)	− 0.6	36
June 13.45559	16 13 11.70	− 7 59 22.0	+1.36	− 9.8	68
15.40927	17 34.34	6 32 52.2	1.00	9.8	72
18.48806	24 30.65	4 22 35.2	0.73	1.3	87
19.44589	26 40.03	3 43 53.3	.22	4.4	89
19.46184	26 42.50	3 43 18.1	.52	7.5	88
23.45744	35 44.60	1 11 40.2	.54	1.9	107
24.40978	37 53.68	0 38 10.2	.55	7.2	102
25.45223	40 14.65	− 0 2 43.7	.38	16.2	108
27.46784	16 44 47.07	+ 1 2 41.4	+0.50	− 9.7	112
July 12.39980	17 17 33.27	+ 6 43 17.2	+0.76	− 3.3	138

Marseilles. Borrelly. 26 cm. *B.A.* Nov.

Gr. M.T.	α	δ	Δα	Δδ	*
May 14.37165	15 13 27.51	−29 43 34.6	+0.04	− 2.5	1
18.36692	20 9.30	27 25 58.9	.44	4.5	11
22.35549	27 15.29	24 51 44.8	.14	5.4	20
23.37532	29 8.86	24 9 52.6	.60	7.9	19
24.35691	30 59.12	23 28 40.5	.44	8.3	35
27.35843	15 36 45.99	−21 17 46.7	+0.35	− 1.7	37
June 8.38234	16 1 55.09	−11 53 57.6	+0.11	− 7.8	58
9.39752	4 9.09	11 6 6.8	.17	6.6	61
10.37724	6 19.02	10 20 28.1	.20	−17.1	63
11.37329	8 31.48	9 33 57.8	.04	+ 3.1	60
12.37022	10 44.83	8 48 24.8	.15	− 6.9	69
13.36755	12 58.91	8 3 19.0	.50	12.3	68
15.38741	17 30.73	6 33 53.2	.34	13.7	70
16.38071	19 44.93	5 51 0.0	.36	13.4	86
17.37259	21 58.82	5 9 1.2	.03	15.0	82
22.37443	33 16.98	1 51 8.0	.19	5.0	92
28.37096	16 46 48.66	− 1 30 30.6	−0.32	− 5.0	114

June 28. Comparison-star wrongly identified.

Nashville. Barnard. 6 in. R. *A.N* 2788, 2799, 2808.

Gr. M.T.	α	δ	Δα	Δδ	*
May 12.70370	15 10 48.93	−30 35 12.8	+1.72	+30.4	3
13.67494	12 21.19	30 5 46.9	1.25	−14.0	2
14.67514	13 57.95	29 33 39.8	1.11	+ 2.3	1
14.74035	14 3.79	29 31 46.9	0.61	−12.3	1
18.73726	20 48.02	27 12 21.2	+0.66	− 5.1	13
24.69693	31 35.87	23 15 0.7	(−1.41	+ 3.6)	25
25.66752	33 29.40	22 32 23.9	+0.94	− 6.8	31
25.68133	33 30.73	22 31 52.1	.68	12.0	34
26.72988	35 32.21	21 45 49.9	0.35	− 8.7	28
28.76663	15 39 34.26	−20 14 13.1	+1.16	+ 0.9	44
June 9.71467	16 4 52.29	−10 51 14.3	+1.38	− 6.5	61
9.72251	4 53.78	10 50 43.8	1.84	+ 2.0	59
10.69479	7 1.62	10 5 30.8	0.58	− 5.9	63
11.72622	9 19.05	9 17 39.5	.49	+ 6.8	65
16.71035	20 29.70	5 36 52.1	.44	− 8.7	79
17.66000	22 38.31	4 56 53.8	.60	8.4	82
17.66903	16 22 39.63	− 4 56 31.9	+ .69	− 9.0	83

Nashville. Barnard. 6 in R. *A.N.* 2788, 2799, 2808.

Gr. M.T.	α	δ	Δα	Δδ	*
	h m s	° ′ ″	s	″	
June 18.63047	16 24 49.44	− 4 16 57.8	+0.71	−12.9	88[1]
20.65218	29 24.81	2 56 25.1	1.34	7.4	94
23.65854	16 36 12.48	− 1 4 34.7	+1.16	− 7.3	96
July 9.62550	17 11 37.33	+ 5 58 12.5	1.04	− 6.1	128
9.65300	11 40.11	5 58 42.8	0.27	4.8	127
9.66477	11 42.15	5 58 54.4	0.79	5.7	132
9.66869	11 42.89	5 58 58.9	1.02	5.3	131
11.73836	16 8.96	6 33 12.2	0.95	5.9	134
13.66971	20 14.47	7 1 20.9	.41	5.1	147
14.67653	22 21.79	7 14 41.3	.34	0.4	133
15.65407	24 25.30	7 26 35.0	0.73	5.7	143
19.64170	32 42.44	8 6 52.2	1.22	5.1	149
20.65874	34 47.33	8 15 2.4	0.89	6.1	151
26.78141	17 47 10.98	+ 8 48 28.0	+1.37	−10.0	156
Aug. 10.67965	18 16 4.97	+ 8 44 15.3	(−2.18	−39.0)	165
11.68015	18 17 57.40	+ 8 41 52.1	(−3.22	+20.1)	165

June 18, July 8, 13, 16. No accurate places of the comparison-stars.

Nice. Charlois. 38 cm. *Bull. Astr.* June.

Gr. M.T.	α	δ	Δα	Δδ	*
June 14.46407	15 13 36.86	−29 40 36.5	+0.47	− 3.4	1
17.47329	18 37.30	27 58 18.2	.45	5.7	7
18.44711	20 17.53	27 23 2.9	.35	5.0	11
20.41350	23 44.67	26 8 47.8	.27	3.5	17
21.42043	25 33.56	25 29 18.5	.64	4.3	18
22.45050	27 26.10	24 47 52.8	.48	5.2	20
23.43402	29 15.21	24 7 21.9	.38	3.8	19
27.44854	36 56.49	21 13 55.2	.22	11.9	26
27.44854	15 36 56.48	−21 13 52.2	+0.21	− 8.9	45
July 7.36896	17 6 43.37	+ 5 15 45.3	+0.22	− 6.0	124
11.36625	15 20.57	6 27 23.1	.22	4.8	136
18.40294	30 7.95	7 55 53.5	.11	+ 1.2	149
23.40094	17 40 21.82	+ 8 33 22.2	+0.27	+ 1.7	154

Nicolajew. Kortazzi. 9 in. *A.N.* 2788.

Gr. M.T.	α	δ	Δα	Δδ	*
May 14.44389	15 13 34.57	−29 41 8.1	+0.13	+ 4.1	6
15.38764	15 8.47	24 9 58.2	(1.42	+14.5)	8
17.40076	18 29.16	18 0 49.1	−0.28	− 1.5	7
18.38868	20 11.75	27 25 7.5	+ .63	1.0	11
21.38625	15 25 29.46	−15 30 44.4	+0.26	− 8.8	18

Orwell Park. Plummer. 10 in. *M.N.* Nov.

Gr. M.T.	α	δ	Δα	Δδ	*
June 9.46403	16 4 17.91	−11 3 1.9	+0.19	− 9.0	59[2]
10.44986	6 29.00	10 16 46.3	.53	+ 1.8	64
12.48177	10 59.99	8 43 14.2	.37	− 1.2	69
13.45465	13 10.05	7 59 26.7	.84	−14.0	68
15.51720	17 48.69	6 28 0 0	.78	+ 0.7	72
17.45750	22 10.44	5 5 13.5	.15	− 0.7	83
18.45238	24 25.33	4 24 15.0	.24	13.5	88[1]
20.45384	28 56.86	3 3 52.2	.30	− 8.2	88[2]
22.51529	16 33 36.60	− 1 45 49.4	+0.32	+ 1.2	100
July 11.45022	16 15 31.48	+ 6 28 41.2	+0.37	− 6.4	134
12.47586	17 42.50	6 44 35.7	.27	+ 7.5	140
13.46525	19 48.36	6 58 49.1	.24	11.6	145
14.46847	21 55.57	7 12 10.6	.39	8.7	139
18.45757	30 14.65	7 56 33.9	.03	+10.7	149
19.48311	32 21.73	8 5 28.2	.15	− 8.1	148
20.46836	16 34 23.04	+ 8 13 46.9	+0.01	+ 6.7	153

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Orwell Park. Plummer. 10 in. *M.N.* Nov.

Gr. M.T.	α	δ	Δα	Δδ	*
	h m s	° ′ ″	s	″	
July 21.47249	16 36 26.53	+ 8 20 58.1	+0.25	— 9.1	154
24.46698	42 30.92	8 39 7.7	.10	+ 9.1	156
27.50462	48 36.83	8 51 12.9	.62	14.4	157
28.50153	17 50 35.48	+ 8 53 51.6	+0.28	+10.2	157

Padua. Abetti. 7 in.? *A.N.* 2823.

Gr. M.T.	α	δ	Δα	Δδ	*
May 14.51634	15 13 42.21	—29 38 59.3	+0.76	— 7.7	1
18.47724	20 20.97	27 21 55.5	.66	4.0	11
20.49040	23 53.01	26 5 55.1	.38	8.7	16
20.49040	23 53.24	26 5 51.9	.61	5.5	17
21.45571	25 37.57	25 28 54.2	.83	5.2	18
24.46965	31 7.84	23 24 48.3	.39	3.2	32
24.46965	15 31 7.84	—23 24 49.9	+0.39	— 4.8	33
June 7.37704	15 39 43.45	—12 41 33.7	+0.39	— 4.9	51
8.37370	16 1 54.37	11 54 21.4	.53	7.1	58
8.37370	1 54.13	1 54 28.3	.29	14.0	58[1]
23.47867	16 35 47.63		+0.69		97
23.48737		— 1 10 44.8		—11.1	97

Palermo. Agnello. 25 cm. *A.N.* 2788, 2790.

Gr. M.T.	α	δ	Δα	Δδ	*
May 15.41719	15 15 10.75	—29 9 24.7	+0.77	—11.2	9
21.44685	23 34.27	25 29 19.7	(—1.51	68.6)	18
28.38754	38 48.50	20 31 33.0	+0.76	6.0	47
30.37860	42 49.57		1.33		50
31.35450	15 44 49.30	—18 15 0.6	+1.21	—18.0	49

May 15. Zona, observer.

Prague. Weinek and Gruss. 6 in. R. *A.N.* 2788.

Gr. M.T.	α	δ	Δα	Δδ	*
May 27.39249	15 36 50.42	—21 16 20.2	+0.76	— 6.5	37
27.41442	15 36 52.94	—21 15 16.5	+0.70	— 1.6	37

Rome. Cerulli. 9 in. R. *A.N.* 2787, 2801.

Gr. M.T.	α	δ	Δα	Δδ	*
	h m s	° ′ ″	s	″	
May 14.43434	15 13 34.11	—29 41 38.7	+0.59	— 7.9	1
15.41784	15 15 9.90	—29 9 14.2	—0.14	— 2.0	9
July 8.36730	17 8 53.19	+ 5 35 11.1	—0.02	— 5.5	125
10.38359	13 14.42	6 11 16.2	+ .33	— 6.8	132
11.38434	15 22.55	6 27 46.7	— .12	+ 1.6	134
12.39276	17 31.91	6 43 11.3	+ .28	— 3.0	140
13.36287	19 35.56	6 57 10.5	+ .44	— 1.7	142
14.37836	21 43.64	7 10 52.4	— .16	+ 0.5	144
15.35634	23 47.53	7 23 11.7	+ .40	+ 4.5	144
16.42534	26 1.56	7 35 26.3	.24	— 5.5	146
17.38343	28 1.35	7 45 41.7	.32	(—78.1)	146
21.36128	36 12.84	8 20 23.0	.18	+ 3.0	151
22.36046	38 15.28	8 27 24.8	.44	20.0	154
24.41052	17 42 23.98	+ 8 38 57.4	+0.00	+15.6	155
Aug. 6.32891	18 7 49.20	+ 8 56 3.7	(—0.19	+22.5)	162
7.32986	18 9 44.21	+ 8 53 58.0	—0.35	+10.6	162

May 14, 15. Millosevich, observer.
August 6. Observation doubtful.

Scarborough. Lohse. 15.5 in. *M.N.* 47.

Gr. M.T.	α	δ	Δα	Δδ	*
May 20.47065	15 23 50.73	—26 6 38.1	+0.21	— 5.7	17
21.51326	25 42.98	25 25 36.9	— .02	4.4	18
29.52798	15 41 5.08	—19 39 30.9	+0.29	— 6.4	49[1]

Washington. Frisby. 9.6 in. *A.J.* 157.

Gr. M.T.	α	δ	Δα	Δδ	*
May 14.69101	15 13 59.30	—29 33 11.0	+0.93	+ 0.1	1
19.73697	22 32.08	26 34 49.6	— .22	— 3.1	15
21.61634	15 25 55.09	—25 21 34.8	+0.87	— 8.9	18

ADDITIONAL OBSERVATIONS.

After the solution of the normal equations there appeared, in *A.N.* 2835, observations made on ten nights by Herr Kammermann at Geneva, and in *A.N.* 2837, observations on eight nights by M. Stuyvaert at Brussels.

These observations are referred chiefly to anonymous stars, and being distributed among six groups, the only effect, probably, would be slightly to increase the weights.

4. *Errors of Observation.*—In order to assign appropriate weights to a series of observations it is necessary to consider the mean, or probable, error of the series. This depends only upon the accidental errors; to determine which, however, the differences between the observed and computed places must first be freed from systematic errors.

Each difference consists of

I. Systematic errors;

ϵ_e, the error of the preliminary ephemeris

ϵ_p, the personal equation of the observer.

II. Accidental errors;

ϵ_o, the accidental error of observation.

ϵ_s, the error of the star-place.

I. Systematic errors.

a. Error of the preliminary ephemeris.

This error may be determined with sufficient accuracy for purposes of weighting by dividing the observations into groups, and taking the means of the differences with reference to the number of observations. The results are:

Mean Date	Δα	Δδ	No. Obs	Adopted Date.	Wt.
	s	″		1887	
May 22	+0.54	—5.2	92	142	6
June 12	.51	5.8	48	162	3
20	.42	9.3	66	172	4
July 11	.38	—1 2	31	192	2
21	+ .27	+3.9	27	202	2
Aug. 8	—0.13	+0.0	6	222	½

Solving by least squares the six equations of condition furnished, the errors of the ephemeris at any time t days from June 1 are, for right-ascension and declination respectively,

$$\left.\begin{aligned}\epsilon_e &= \quad 0^s.52 + 0^s.00112\,t + 0^s.0000631\,t^2 \\ \epsilon_e &= -5''.5 \ -0''.0123\,t - 0''.001373\,t^2\end{aligned}\right\} \quad (1)$$

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These errors added with changed signs to the differences will reduce them to the errors arising in observation.

b. Personal equation.

The method used to determine the personal equations was to compare the constant part of the error of the ephemeris as given by each observer with that given by the mean of all the observers, this mean being taken as the standard.

Having corrected each difference for the terms depending on t as given by equation (1) and taking the means for the different observers the results were those given in the columns headed $\Delta'\alpha$ and $\Delta'\delta$ in the following table; the next two columns contain the personal equations in right ascension and declination given with such signs that by their addition in the corresponding series the differences are freed from the personal errors of the observers. The last column contains the number of observations from which the mean $\Delta'\alpha$ and $\Delta'\delta$ were obtained.

	$\Delta'\alpha$	$\Delta'\delta$	ε_p α	ε_p δ	No. Obs.
	s	″			
Albany	+0.34	— 2.9	+0.17	—4.6	4
Algiers:					
Rambaud	.47	6.0	+0.04	—1.5	11 10
Trépied	.46	10.7	+0.05	+3.2	16 5
Berlin:					
Battermann	1.21	13.0	—0.70	+5.5	2
Knorre	0.41	6.9	+0.10	—0.6	2
Besançon:					
Gruey	0.41	9.2	+0.10	+1.7	11 5
Guillin	0.23	16.2	+0.28	+8.7	4
Herique	0.67	8.9	—0.16	+1.4	7
Bothkamp	0.53	6.6	—0.02	—0.9	6
Bordeaux:					
Courty	0.26	6.8	+0.25	—0.7	7
Flamme	0.45	5.4	+0.06	—2.1	11 3
Rayet	0.53	8.8	—0.02	+1.3	16 9
Cambridge, Mass.:					
Chandler	0.52	5.4	—0.01	—2.3	5
Wendell	0.10	4.1	+0.41	3.4	10
Cape of G. Hope	0.53	7.4	—0.02	0.1	6
Dresden	0.74	5.6	—0.23	1.9	4
Geneva	0.47	6.5	+0.04	—1.0	15
Gohlis	.79	8.7—	—0.28	(+1.2)	10 9
Göttingen	0.56	15.5	—0.05	(+8.0)	4
Greenwich:					
Downing	0.31	7.8	+0.20	(+0.3)	1
Turner	+0.66	15.2	—0.15	(+7.7)	1
Hamburg	—0.11	0.6	+0.62	—6.9	2
Kiel	+0.80	11.7	—0.29	+4.2	3
Marseilles	0.26	8.3	+0.25	+0.8	17
Nashville	0.91	6.2	—0.40	(—1.3)	28 18
Nice	0.39	4.6	+0.12	—2.9	13 9
Nicolajew	0.17	2.0	0.34	5.5	4
Orwell Park	0.45	5.2	+0.06	2.3	20 9
Padua	0.55	7.0	—0.4	—0.5	11
Palermo:					
Agnello	+1.10	—12.0	—0.59	+4.5	3 2

	$\Delta'\alpha$	$\Delta'\delta$	ε_p α	ε_p δ	No. Obs.
	s	″			
Zona	+0.77	—11.4	—0.26	+3.9	1
Prague:					
Gruss	0.70	1.6	0.19	—5.9	1
Weinek	0.76	6.5	—0.25	1.0	1
Rome:					
Cerulli	0.30		+0.21		13
Millosevich	0.22	5.2	+0.29	2.3	2
Washington	+0.53	—4.1	—0.02	—3.4	3
Mean	+0.51	—7.5			

In taking the above means, each independent observer was given equal weight; when only a few observations are made the personal error may, of course, be masked by the accidental errors, but in the mean these errors are nearly eliminated by a number of such short series. In fact, taking the means somewhat with regard to the number of observations, the results were $+0^s.51$ and $-7''.4$.

In July the comet became elongated north and south, and difficult to observe in declination. By this change of form the accidental errors become larger, and there is reason to suppose that the personal error of observing in declination may have changed. Hence the observations made in July and August were not used in determining the personal equations; and since not enough observations were made for a separate determination, no personal equations were applied to the observations made during these months.

In observations made with a ring-micrometer the personal equation in declination has opposite effects, according as the comet is north or south of the star, and is nearly eliminated in a number of observations. The personal equations cannot therefore be obtained without a consideration of the relative positions of the star and the comet. The quantities corresponding to them are inclosed in brackets, and they should be, when depending upon a number of observations, small.

The Harrow, Kremsmünster, and Scarborough observations were received too late to be used in determining the personal equations.

Since the observations have been used once with equal weights for all the observations by an independent observer, their weights in the formation of the normal places must be reduced in consequence. When only one observation was made, it was used only in the determination of personal equation; when two were made, each was given only half weight in the formation of the normal places; when three were made the weight of each was reduced one-third, and so on until the reduction became insignificant.

II. Accidental Errors.

Errors of observation and star-places. Determination of probable error.

Each difference between the observed and computed positions may be reduced so as to contain only these errors and the personal error, by correcting for the terms involving t, as given by equation (1), and for the constant terms,

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$0^s.51$ and $7''.5$, given by the mean of all the observations. These corrections are given for every tenth day, in the following table:

	$\Delta(\Delta\alpha)$	$\Delta(\Delta\delta)$
	s	''
May 12	—0.51	+7.20
22	0.51	7.48
June 1	0.51	7.50
11	0.493	7.24
21	0.463	6.70
July 1	0.419	5.90
11	0.364	4.82
21	0.296	3.46
31	0.215	+1.83
Aug. 10	—0.123	—0.07

The corrections from this table being added to the differences of a given observer, the mean of the resulting differences will with changed sign, be the personal error of that observer.

Let $v_1, v_2, \ldots v_i$ be the residuals of the individual differences from this mean, then

$$v^2 = \varepsilon_0^2 + \varepsilon_s^2$$

If ε_1 be the mean error of observation in an observation depending upon a single comparison,

$$\varepsilon_1^2 = \frac{[n\varepsilon_0\varepsilon_0]}{i-1}$$

where $[n\varepsilon_0\varepsilon_0] = n_1\,\varepsilon_{0\,1}^2 + n_2\,\varepsilon_{0\,2}^2 + \ldots + n_i\,\varepsilon_{0\,i}^2$

Substitution gives

$$\varepsilon_1^2 = \frac{[nv\,v] - [n\varepsilon_s\,\varepsilon_s]}{i-1}\,; \tag{2}$$

and the mean error of an observation depending upon a number of comparisons n is

$$\varepsilon = \sqrt{\left(\frac{\varepsilon_1^2}{n} + \varepsilon_s^2\right)} \tag{3}$$

When the star-places are carefully determined, ε_s will usually be small in comparison with ε_0 and the probable error will then be approximately given by

$$r = 0.6745\sqrt{\frac{[nvv]}{n(i-1)}}\,, \tag{4}$$

which is the formula commonly used.*

There is however an objection to weighting strictly in accordance with this, or any other similar formula. On each night there are undetermined instrumental and personal errors peculiar to that night; such errors are not diminished by an increased number of comparisons, hence the insufficiency of a formula in which the probable error depends solely upon the number of comparisons. I have used (4) when the number of comparisons did not exceed sixteen, but I have assumed that the probable error was not diminished by a number of comparison greater than this. This limit is probably too great, while the comet was strongly condensed.

The calculated probable errors of a single comparison, arranged in order of the size of the instrument, are:

Place and Observer	Probable Error		Aperture
	s	''	cm
Algiers, Rambaud	1.02	6.6	50
" Trépied	0.92	10.8	50
Cambridge, Wendell	0.50	6.3	38
Nice, Charlois	0.18	{ 1.4 5.5	38
Bordeaux, Courty	1.03	10.8	36
" Flamme	0.45	9.9	36
" Rayet	0.79	{ 7.6 12.3	36
Marseilles, Borrelly	0.31	6.7	26
Orwell Park, Plummer	0.39	{ 15.0 17.3	25
Geneva, Kammermann	0.82	8.7	25
Rome, Cerulli	0.47	6.8	23 R
Besançon, Gruey	0.94	(*28.0)	20
" Herique	0.67	11.9	20
Padua, Abetti	0.44	5.5	18?
Gohlis, Winkler	0.65	26.0	15 R
Kremsmünster, Schwab	0.61	9.3	15 R
Nashville, Barnard	0.61	8.4	15 R

* Adopted probable error, 20''.

When two errors are given, the latter refers to the observations made in July and August when the comet was more difficult to observe in declination; in most cases there was no difference. All the Rome observations were made during these months. As a guide to assigning probable errors in accordance with the size of the instrument used, I have grouped these results.

Aperture	Mean Aper.	Prob. Error		No. of Obs.
cm cm	cm	s	''	
15 — 18	16	0.58	12.3	4
20 — 26	24	0.60	10.1	5 , 4
36 — 38	37	0.59	8.1	5

The solution of the equations of condition, taken with equal weights, shows that the probable error in declination may be nearly represented by the equation

$$r = 10''.3 + (25-a)\,0''.20\,, \tag{5}$$

for apertures between 15^{cm} and 40^{cm}, a being the aperture in centimeters. The probable error in right-ascension appears to be independent of the aperture.

The probable error of each observer was calculated by (4) when the number of observations was seven or more. In other cases it was, the aperture of instrument being the only available guide, assigned by (5) and taken as $0^s.60$ in right-ascension. The weight was then calculated by

$$p = \frac{r_0^2}{r^2} = \frac{(5''.5)^2}{r^2}$$

* The accurate formula is, however, not much more difficult in application, and when the error of observation is small, the discrepancies arising from the use of the approximate formula may become appreciable. The mean error would be determined from (2) by assigning to each observation a value of ε_s in accordance with the mean error of the catalogue on the authority of which the place of the comparison-star rested; then, for each observation,

$$r = 0.6745\sqrt{\frac{\varepsilon_1^2}{n} + \varepsilon_s^2}\,,$$

ε_s being assigned as before.

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5″.5 being assumed as the probable error of a single comparison in a standard observation.

5. *Formation of Normal Places.* — Weights being given to each observation, and personal equation applied, in accordance with the preceding results, the residuals were divided into groups, and their weighted means taken.

Group	Mean Date	(O—C) $\Delta\alpha$	(O—C) $\Delta\delta$	No. of Obs.	Weight
		s	″		
May 12–21	17.8	+0.620	— 6.65	48	152 180
May 22–31	26.0	.503	6.80	42	146 168
June 1–16	12.9	.502	7.70	63 62	214 136
June 17–30	21.8	.385	8.57	68	206 135
July 1–14	10.5	.377	— 1.32	34 33	104 75
July 15–31	22.2	.303	+ 2.04	27 26	115 43
Aug. 1–10	8.4	+0.141	+ 4.20	6	25 14

The corresponding normal places are:—

Date	α	δ
	° ′ ″	° ′ ″
1887 May 18.0	229 52 47.92	—27 39 28.87
26.0	233 31 43.66	22 17 58.58
June 13.0	243 2 12.91	8 19 54.68
22.0	248 6 29.18	— 2 5 11.54
July 10.0	258 5 2.11	+ 6 4 43.29
22.0	264 22 33.85	8 24 39.87
Aug. 8.0	272 45 11.59	+ 8 52 17.07

6. *Formation of Normal Equations and Determination of Definitive Elements.* — The coefficients of the variations of the elements were computed by the formulas given by Oppolzer.* Whence were formed the following

* Lehrbuch zur Bahnbestimmung. Zweiter Band, pp. 405–406.

Equations of Condition (coefficients logarithmic).

Right-Ascension.

0.9158 $\Delta\alpha\cos\delta$ =	9.1014 $\delta i'$ +	n9.7910 $\sin i'\,\delta\Omega'$ +	0.5091 $\delta\pi'$ +	0.6943 $\delta\log q$ +	n8.6336 δT +	n9.4702 δe
0.8439	9.3201	n9.7866	0.5296	0.6382	n8.6698	n9.3811
0.8722	9.5725	n9.6509	0.5267	0.3633	n8.6929	n8.6523
0.7601	9.6108	n9.4889	0.4993	0.0396	n8.6719	8.8019
0.7465	9.5663	n8.5065	0.4145	n9.9454	n8.5856	9.3627
0.6557	9.4678	9.0244	0.3502	n0.2324	n8.5105	9.4675
0.3323	9.2351	+ 9.3578	+ 0.2622	+ n0.3689	+ n8.3957	+ 9.5169

Declination.

n0.8228 $\Delta\delta$	= n0.5027	+ n9.7115	+ 9.0392	+ 9.9016	+ n6.7537	+ 7.5274
n0.8325	n0.5168	n9.9688	9.3296	9.4857	n7.4650	n8.1708
n0.8865	n0.4630	n0.2538	9.7602	n0.1533	n7.9423	n7.9174
n0.9330	n0.3902	n0.3102	9.8723	n0.3483	n8.0196	8.1229
n0.1399	n0.1846	n0.3282	9.9686	n0.4771	n8.0424	8.6720
0.3032	n0.0168	n0.3278	9.9782	n0.4762	n7.9908	8.7276
0.6149	n9.7208	+ n0.2965	+ 9.9526	+ n0.4242	+ n7.9062	+ 8.6984

After multiplying each equation by the square root of its weight, and rendering all the equations homogeneous by the introduction of the factors

$$x = 1.6303\ \delta i' \qquad t = 1.7852\ \delta\log q$$
$$y = 1.3754\ \delta\Omega'\sin i \qquad u = 9.8581\ \delta T$$
$$z = 1.6919\ \delta\pi' \qquad w = 0.7159\ \delta e$$
$$\text{residual unit} = 2.0374$$

the normal and elimination equations were obtained and checked in the usual way.

Normal Equations (natural numbers).

+3.2495 x	+2.4326 y	+0.0344 z	+0.6054 t	—0.0712 u	+0.0262 w	=	+3.2908
+2.4326	+3.5101	—1.5012	+0.3476	+1.3998	+0.3285	=	+1.3221
+0.0344	—1.5012	+3.8590	+1.8300	—3.7560	—0.3742	=	+3.2762
+0.6054	+0.3476	+1.8300	+2.8651	—1.7499	+1.5851	=	+2.5187
—0.0712	+1.3998	—3.7560	—1.7499	+3.6648	+0.3049	=	—3.1962
+0.0262	+0.3285	—0.3742	—1.5851	+0.3049	+1.5346	=	—0.5268

Elimination Equations (coefficients logarithmic).

+0.51181 x	+0.38607 y	+8.53656 z	+9.78204 t	+n8.85248 u	+8.41830 w	=	0.51730
	0.22763	n0.18384	n9.02366	0.16230	9.48982	=	n0.05748
		0.39412	0.23756	n0.38766	n8.97864	=	0.34428
			0.18772	8.75435	n0.17734	=	9.46761
				7.74036	7.14613	=	8.38021
					7.69897	=	8.32015

Direct solution of these equations gave

$\log x = 0.3653$	$\delta i' = +\ 5.92$	$\log t = 0.6181$	$\delta\log q = +0.0000360$
$\log y = 0.4387$	$\delta\Omega' = -33.13$	$\log u = 0.5185$	$\delta T = +0.002418$
$\log z = 0.1488$	$\delta\pi' = +\ 3.12$	$\log w = 0.6212$	$\delta e = +0.0004249$

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The small coefficients in the equations involving u and w alone, show that the values obtained by direct solution are highly uncertain. An attempt was made to diminish this uncertainty by expressing the other unknown quantities in terms of w and an absolute term. Accordingly,

$$\begin{aligned} x &= 9.93648 + 0.16283\, w \\ y &= 9.39094 + n0.47594\, w \\ z &= 0.71350 + n0.57532\, w \\ t &= 8.47124 + 0.61496\, w \\ u &= 0.63985 + n0.02695\, w \end{aligned}$$

the coefficients being logarithmic.

Substitution in the equations of condition and solution of the fourteen resulting equations for w gave

(1) $$\log w = 0.6604\,;$$

the corresponding changes of the elements are given in the column numbered I in the table below. Comparison with the normal places gave — 9″.86 as the sum of the weighted residuals, showing that the uncertainty of solution had not been wholly eliminated. To determine by trial what variation of the eccentricity would best distribute the residuals, an assumption was made, —

(2) $$\log w = 0.6814,$$

which gave the changes of the elements numbered II. Comparison with the normal places gave the residuals numbered II. Interpolation between the values (1) and (2) gave

(3) $$\log w = 0.6788$$

The results of this assumption are given in the columns numbered III. They show no improvement on the results of the second hypothesis. The residuals given by direct comparison being so nearly equal, it was considered safe to interpolate between them, on the assumption that the sum of the weighted residuals should be zero. The weighted values are numbered (IV) and the sum of their squares being slightly smaller than for the other assumed variations of the eccentricity, the value

(4) $$\log w = 0.6801$$

was taken as the definitive value.

Changes of Elements.

	I	II	III
δT	+ 0.002344	+ 0.002301	+ 0.002307
$\delta \pi'$	+ 2″.33	+ 1″.88	+ 1″.94
$\delta i'$	+ 6.27	+ 6.47	+ 6.45
$\delta \Omega'$	—36″.59	—38″.55	—38″.33
$\delta \log q$	+ 0.0000393	+ 0.0000413	+ 0.0000411
δe	+ 0.0004650	+ 0.0004880	+ 0.0004852

Residuals (Normal — Computed).

Unweighted.		Weighted		
II	III	II	(IV)	III
Right-Ascension.				
+1″.08	+0″.91	+1″.33	+1″.23	+1″.12
—0.59	—0.57	—0.72	—0.71	—0.70
+0.21	+0.17	+0.31	+0.28	+0.25
—0.89	—0.94	—1.28	—1.31	—1.35
+0.61	+0.53	+0.62	+0.58	+0.54
0.72	0.64	0.77	0.73	0.68
+0.80	+0.76	+0.40	+0.39	+0.38
Declination.				
—0.60	—0.84	—0.80	—0.96	—1.13
+0.59	+0.25	+0.76	+0.54	+0.32
+0.75	+0.41	+0.88	+0.68	+0.48
—1.43	—1.77	—1.66	—1.86	—2.05
+0.81	+0.53	+0.70	+0.58	+0.46
+0.75	+0.34	+0.50	+0.36	+0.22
—1-27	—1.67	—0.47	—0.54	—0.62
Sum +1.54	—1.25	+1.36	—0.01	—1.40

All the weights have been divided by 100 for convenience. The sums of the squares of the residuals are:

	II	(IV)	III
Unweighted	10″.02	10″.11	10″.59
Weighted	10.87	10.72	10.96

Transforming the preliminary elements from the ecliptic to the equator, and adding the changes interpolated between II and III, the resulting definitive elements of Comet 1887 IV are:

$$\begin{aligned} T &= \text{June } 16.663384 \text{ Gr. M.T.} \\ \left.\begin{aligned} \pi' &= 257^\circ\ 4'\ 4''.38 \\ \Omega' &= 313\ \ 54\ \ 12\ .14 \\ i' &= 22\ \ 20\ \ \ 9\ .02 \end{aligned}\right\} &\ \text{Mean Equator 1887.0} \\ \log q &= 0.1442046 \\ e &= 0.9960879 \end{aligned}$$

Constants for the Equator.

$$\begin{aligned} x &= r\,[9.9830763]\,\sin(349^\circ\ 18'\ 5''.82+v) \\ y &= r\,[9.9843699]\,\sin(254\ \ 50\ \ 26\ .90+v) \\ z &= r\,[9.5798234]\,\sin(303\ \ \ 9\ \ 52\ .24+v) \end{aligned}$$

Leander McCormick Observatory, Univ. Virginia, 1888 *May* 26.

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THE

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THE MOTION OF *HYPERION* AND THE MASS OF *TITAN*,

By G. W. HILL.

The diversity of the values assigned to the mass of *Titan*, the bright satellite of *Saturn*, has led me to look into the matter. No doubt it will seem of more importance to the practical astronomer to make close predictions of the future positions of *Hyperion* than merely to gratify a scientific curiosity as to the mass of *Titan*. But the attainment of the first end may be very much facilitated by correct knowledge as to the latter element.

I begin with certain generalities in reference to the problem of three bodies. Let us suppose that two planets or satellites are circulating about their central body in the same plane, and that their motion is of a stable character. Then, adopting the notation of Delaunay, D the mean elongation, l the mean anomaly of the one and l' that of the other, the longitudes and radii can be expressed, in a convergent manner, by infinite series of the forms

$$\begin{aligned} V \text{ or } V' &= \text{mean long.} + \Sigma\, A \sin(iD+jl+j'l') \\ r \text{ or } r' &= \Sigma\, B \cos(iD+jl+j'l') \end{aligned}$$

Here i, j and j' are positive or negative integers, and the coefficients A and B have, as a factor, $e^{\pm j}\, e'^{\pm j'}$, where the ambiguous signs are so taken that the exponents may be positive. From whatever points in the plane we suppose that the planets set out, e and e' depend on the initial velocities and their directions. Then the latter can be so adjusted that we have $e = o$ and $e' = o$. It will be seen that this is equivalent to making four out of the eight arbitrary constants of the problem vanish. In this case we have

$$\begin{aligned} V \text{ or } V' &= \text{mean long.} + \Sigma\, A \sin iD \\ r \text{ or } r' &= \Sigma\, B \cos iD \end{aligned}$$

The inequalities of the longitudes and the radii can therefore be tabulated in tables to single entry with the argument D. Differentiating the second equation we obtain

$$\frac{dr}{dt} \text{ or } \frac{dr'}{dt} = -(n-n')\, \Sigma iB \sin iD$$

which shows that, in conjunction or opposition, not only are the true longitudes equivalent to the mean, but that then the planets move perpendicularly to their radii. This does not exclude the possibility of their so moving at other points of their orbits; in the case of *Hyperion* this particular direction of motion occurs twice between conjunction and opposition.

The possibility of the special case of the problem of three bodies which has just been described may be still further illustrated. Let, at a certain moment, the planets be seen in conjunction from the central body. If, at this moment, the directions of their motions relative to the central body are perpendicular to their radii and in the same plane, the circumstances of their motion, before and after the mentioned conjunction, are identical but in reverse order with respect to the time. That is, if t the time is counted from the moment of conjunction, the radii will be functions of t^2; and if the longitudes of the planets are counted from the line of the conjunction they will be equivalent to functions of t^2 multiplied by t. For let us grant that the longitudes are measured in the reverse direction, and that time past is considered as future. These changes are effected by writing $-t$, $-V$ and $-V'$ for t, V and V' in the differential equations of motion. They are unaltered by this. In addition the four quantities

$$\frac{dr}{dt} = o,\ \frac{dr'}{dt} = o,\ \frac{dV}{dt} \text{ and } \frac{dV'}{dt}$$

are the same in both cases. Thus is apparent the truth of our statement.

The planets now setting out from conjunction, one will generally have a more rapid motion in longitude than the other. Let this be the one nearer the central body, and let the motion of both be followed until the angular distance between them has reached 180°, or until they are seen in opposition at the central body. We may now consider the angles the directions of their motions at this time form with their radii. With velocities assigned at random to them at the moment of starting from conjunction, they will, most probably, reach the state of opposition with these angles somewhat different from right angles. But, provided that the ratios of the two planetary masses to that of the central body, and the ratio of the radii at the moment of conjunction are contained within certain limits, which undoubtedly leave

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a large field for selection of values, it will be found that we can adjust the initial velocities of the two planets in such a manner that, when they reach the state of opposition, they will again move perpendicularly to their radii.

Granting that this adjustment has been made, it is evident, from the same reasoning as before, that the circumstances of motion of the planets, before and after the moment of opposition, are identical, but in reverse order with respect to the time. It follows from this that, the motion being continued, the planets will advance from opposition to conjunction again in the same time as they took to pass from conjunction to opposition; and when they arrive there will have the same radii and the same velocities as when they last were in conjunction. Hence, in passing from one conjunction to the next, they have gone through a complete round of all the phases of their motions relatively to each other and to their central body.

When the principle of FOURIER's theorem is invoked to supply us the periodic series exhibiting the values of the coordinates, it is readily seen that they depend on a single argument as D which augments by a circumference during a synodic period of the two planets, and that they have the forms which have already been given.

From the observations which have been made of *Hyperion* it appears that it is quite approximately in the case we have described, that is to say that its radius is very nearly at a standstill when it is either in conjunction or opposition with *Titan*. It is true that *Titan* is known to have a proper eccentricity of 0.028, which must trouble to some extent this condition of motion. But it seems quite legitimate to neglect this effect in a first approximation, and it is proposed to solve the problem of the perturbations of *Hyperion* and the mass of *Titan* as if the mentioned condition were rigorously fulfilled. The problem is simplified by assuming that the mass of *Hyperion* is insensible, and consequently that *Titan* moves uniformly in a circular orbit.

The elements needed for the solution, and which must be furnished by observation, are four in number. Those which will be here employed are as follows:

Daily motion of *Titan*	$= 22^\circ.5770090$
Average daily motion of *Hyperion*	$= 16^\circ.9198837$
Constant radius of *Titan*	$= 176''.915$
Radius of *Hyperion* in opposition	$= 192''.582$

The first of these data is due to BESSEL, whose elements of *Titan* appear to be still not antiquated. The remaining three are due to Prof. ASAPH HALL, *Hyperion's a* being multiplied by 0.9 to produce the opposition radius. From these data we get the following deductions:

Synodic period	$= 63^d.6365612$
Half synodic period	$= 31^d.8182806$
Motion of *Titan* in half synodic period	$= 718^\circ.361609$
" " *Hyperion* in half syn. per.	$= 538^\circ.361609$
" " Conj. line " "	$= -1^\circ.638391$

Calling the angle the direction of motion makes with the radius ψ, the equation for ψ is

$$\cot.\,\psi = \frac{e}{\sqrt{(1-e^2)}} \sin E$$

Supposing that *Hyperion* sets out from opposition as its perisaturnium with an eccentricity $= 0.1$, at conjunction, without any action from *Titan*, we shall have $\psi = 90^\circ\, 8'\, 58''.85$. But through the action of *Titan* this is reduced to 90°. This is a permanent effect, and may be used to discover the mass of *Titan*.

And, in order to get a preliminary value of this mass to be used in the more serious portion of the work, I computed the motion of the line of apsides during the half synodic period from opposition to conjunction, neglecting all but the first power of the disturbing force. The mass of *Titan* was put $= 0.0001$, *Hyperion's* eccentricity $= 0.1$ and half a day was adopted as the interval. The result is shown in the following table:

	$\sum \frac{d\omega}{dt}$	$\frac{d\omega}{dt}$		$\sum \frac{d\omega}{dt}$	$\frac{d\omega}{dt}$		$\sum \frac{d\omega}{dt}$	$\frac{d\omega}{dt}$
d	″	″	d	″	″	d	″	″
0.0	0.000		4.5	−138.547		9.0	+ 247.832	
		−33.977			+22.332			+ 39.809
0.5	− 33.977		5.0	116.215		9.5	287.641	
		32.451			30.797			31.326
1.0	66.428		5.5	85.418		10.0	318.967	
		29.427			38.373			21.120
1.5	95.855		6.0	47.045		10.5	340.087	
		24.962			44.650			+ 9.595
2.0	120.817		6.5	− 2.395		11.0	349.682	
		19.158			49.260			− 2.765
2.5	139.975		7.0	+ 46.865		11.5	346.917	
		12.171			51.898			15.420
3.0	152.146		7.5	98.763		12.0	331.497	
		− 4.218			52.342			27.793
3.5	156.364		8.0	151.105		12.5	303.704	
		+ 4.419			50.468			39.297
4.0	−151.945		8.5	+201.573		13.0	+ 264.407	
		+13.398			+46.259			− 49.358

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	$\sum\frac{d\omega}{dt}$	$\frac{d\omega}{dt}$		$\sum\frac{d\omega}{dt}$	$\frac{d\omega}{dt}$		$\sum\frac{d\omega}{dt}$	$\frac{d\omega}{dt}$
d	"	"	d	"	"	d	"	"
13.5	+215.049		20.0	—229.544		26.5	+ 22.043	
		—57.446			+34.936			—75.448
14.0	157.603		20.5	194.608		27.0	— 53.405	
		63.104			41.278			102.533
14.5	94.499		21.0	153.330		27.5	155.938	
		65.972			45.159			132.593
15.0	+ 28.527		21.5	108.171		28.0	288.531	
		65.820			46.589			165.886
15.5	— 37.293		22.0	61.582		28.5	454.417	
		62.622			45.620			202.750
16.0	99.915		22.5	— 15.962		29.0	657.167	
		56.464			42.294			243.752
16.5	156.379		23.0	+ 26.332		29.5	900.919	
		47.529			36.607			289.048
17.0	203.908		23.5	62.939		30.0	1189.967	
		36.373			28.508			338.400
17.5	240.281		24.0	91.447		30.5	1528.367	
		23.687			17.915			388.508
18.0	263.968		24.5	109.362		31.0	1916.875	
		—10.270			+ 4.726			430.527
18.5	274.238		25.0	114.088		31.5	2347.402	
		+ 3.045			—11.124			450.091
19.0	271.193		25.5	102.964		32.0	—2797.493	
		15.423			29.741			—440.423
19.5	—255.770		26.0	+ 73.223				
		+26.226			—51.180			

By interpolation from the data of this table the value of $\Delta\omega$ corresponding to the argument 31ᵈ.81828 is about —2634″. But it should be —5898″, consequently the mass of *Titan* should be changed from $\frac{1}{10000}$ to $\frac{1}{4488}$.

Having now some conception of the magnitude of the mass of *Titan*, it is proposed to trace the path of *Hyperion* from opposition to conjunction by mechanical quadratures, neglecting no powers of the disturbing forces. There are two unknown quantities to be determined: first, the velocity with which *Hyperion* should start from opposition; second, the mass of *Titan*. And there are two conditions given which suffice for their determination: first, *Hyperion* must arrive at conjunction with *Titan* after the lapse of 31.81828 days; second, it must at that time be moving at right angles to its radius vector. In order to carry out the process of mechanical quadratures we must assume the values of the two unknowns, leaving them to be corrected afterwards. I assume the velocity of *Hyperion* at starting from opposition to be such that it gives

$$\frac{dV}{dt} = 20°.784043,$$

the unit of time being a day. This is what it would have were it moving in an elliptic orbit in which $e = 0.1$. And for the sake of a round number I shall take the mass of *Titan* $= \frac{1}{4500}$. The perturbations of the longitude and radius were computed by employing the indirect process. The intervals adopted at the beginning were half a day, but as the values of the functions change very rapidly near conjunction it was found expedient at the argument 27ᵈ.75 to reduce them to one-sixth of a day. The principal results obtained are exhibited in the following table. The perturbations, as here given, represent the deviations from the osculating ellipse at opposition. With regard to the radius, the mean distance of *Titan* was adopted as the unit, and, in the table, the unit of the seventh decimal of this is employed as the unit.

	$\sum\frac{d.\delta V}{dt}$	$\frac{d.\delta V}{dt}$	$\sum{}^2\frac{d^2\delta r}{dt^2}$	$\sum\frac{d^2\delta r}{dt}$	$\frac{d^2\delta r}{dt^2}$
d	"	"			
0.0	0.0000			0.000	
		— 0.0541	+ 2.785		+ 66.210
0.5	—0.0541			+ 66.210	
		0.4806	68.995		64.172
1.0	0.5347			130.382	
		1.2944	199.377		60.476
1.5	1.8291			190.858	
		2.4301	390.235		55.597
2.0	4.2592			246.455	
		3.8030	636.690		50.212
2.5	8.0622			296 667	
		5.3274	933.357		44.940
3.0	13.3896			341.607	
		6.9251	1274 964		40.289
3.5	20.3147			381.896	
		8.5345	1656.860		36.602
4 0	28.8492			418.498	
		10.1165	2075.358		33.999
4.5	— 38.9657			+ 452.497	
		— 11.6470	+ 2527.855		+ 32.520

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	$\sum \frac{d.\delta V}{dt}$	$\frac{d.\delta V}{dt}$	$\sum^2 \frac{d^2\delta r}{dt^2}$	$\sum \frac{d^2\delta r}{dt}$	$\frac{d^2\delta r}{dt^2}$
d	″	″			
5.0	— 50.6127	— 13.1162	+ 3012.872	+ 485.017	+ 32.093
5.5	63.7289	14.5333	3529.982	517.110	32.532
6.0	78.2622	15.9123	4079.624	549.642	33.661
6.5	94.1745	17.2745	4662.927	583.303	35.282
7.0	111.4490	18.6460	5281.512	618.585	37.207
7.5	130.0950	20.0557	5937.304	655.792	39.259
8.0	150.1507	21.5355	6632.355	695.051	41.278
8.5	171.6862	23.1185	7368.684	736.329	43.117
9.0	194.8047	24.8431	8148.130	779.446	44.615
9.5	219.6478	26.7458	8972.191	824.061	45.639
10.0	246.3936	28.8692	9841.891	869.700	46.027
10.5	275.2628	31.2576	10757.618	915.727	45.606
11.0	306.5204	33.9591	11718.951	961.333	44.169
11.5	340.4795	37.0247	12724.453	1005.502	41.469
12.0	377.5042	40.5078	13771 424	1046.971	37.218
12.5	418.0120	44.4633	14855.613	1084.189	31.060
13.0	462 4753	48.9447	15970.862	1115.249	22.584
13.5	511.4200	54.0014	17108.695	1137.833	+ 11.317
14.0	565.4214	59.6721	18257.845	1149.150	— 3.250
14.5	625.0935	65.9776	19403.745	1145.900	21.643
15.0	691.0711	72.9092	20528.002	1124.257	44.335
15.5	763.9803	80.4148	21607.924	1079.922	71.647
16.0	844.3951	88.3817	22616.199	1008.275	103.657
16.5	932.7768	96.6138	23520.817	904.618	139.805
17.0	1029.3906	104.8184	24285.630	764.813	179.057
17.5	1134.2090	112.6022	24871.386	585.756	219.522
18.0	1246.8112	119.4445	25237.620	366.234	258.039
18.5	1366.2557	124 7574	25345.815	+ 108.195	290.774
19.0	1491.0131	127.9111	25163.236	— 182.579	313.047
19.5	1618.9242	128.3512	24667.610	495.626	320.519
20.0	1747.2754	125.6494	23851.465	816.145	309.504
20.5	1872.9248	119.6684	22725.816	1125.649	278.431
21.0	1992.5932	110.5826	21321.736	1404.080	228.391
21.5	2103.1758	98.9071	19689.265	1632.471	163.279
22.0	2202.0829	85.4130	17893.515	1795.750	89.036
22.5	2287.4959	71.0055	16008.729	1884.786	— 12.702
23.0	2358.5014	56.6601	14111.241	1897.488	+ 58.537
23.5	2415.1615	43.1114	12272.290	1838.951	119.860
24.0	2458.2729	30.9998	10553.199	1719.091	167.337
24.5	2489.2727	20.6962	9001.445	1551.754	199.326
25.0	2509.9689	12.3526	7649.017	1352.428	215.847
25.5	2522.3215	5.9579	6512.436	1136.581	217.754
26.0	2528.2794	— 1.3770	5593.609	918.827	206.391
26.5	2529.6564	+ 1.5916	4881.173	712.436	182.887
27.0	2528.0648	+ 3.1898	+ 4351.624	529.549	+148.044
27.5	—2524.8750			— 381.505	
27.75	—2523.68161	+1.20138	+3977.6203	— 114.6686	+11.1726
	2522.48023	1.17887	3874.1243	103.4960	9.1016
	2521.30136	1.12578	3779.7299	94.3944	6.8505
28.25	2520.17558	1.04505	3692.1860	87.5439	4.4043
	2519.13053	0.93959	3609.0464	83.1396	+ 1.7461
	2518.19094	0.81271	3527.6529	81.3935	— 1.1451
28.75	2517.37823	0.66760	3445.1143	82.5386	4.2938
	2516.71063	0.50766	3358.2819	86.8324	7.7282
	2516.20297	0.33665	3263.7213	94.5606	11.4793
29.25	2515.86632	+0.15891	3157.6814	106.0399	15.5818
	2515.70741	—0.02094	3036.0597	121.6217	20.0721
	2515.72835	0.19721	2894.3659	141.6938	24.9862
29.75	2515.92556	0.36330	2727.6859	166.6800	30.3568
	2516.28886	0.51126	2530.6491	197.0368	36.2076
	—2516.80012	—0.63151	+2297.4047	—233.2444	—42.5468

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	$\sum \frac{d.\delta V}{dt}$	$\frac{d.\delta V}{dt}$	$\sum {}^2 \frac{d^2\delta r}{dt^2}$	$\sum \frac{d^2\delta r}{dt}$	$\frac{d^2\delta r}{dt^2}$
d	″	″			
30.25	—2517.43163	—0.71233	+2021.6135	— 275.7912	—49.3541
	2518.14396	0.73969	1696.4682	325.1453	56.5685
	2518.88365	0.69680	1314.7544	381.7138	64.0695
30.75	2519.58045	0.56393	868.9711	445.7833	71.6610
	2520.14438	—0.31884	+ 351.5268	517.4443	79.0582
	2520.46322	+0.06281	— 244.9757	596.5025	85.8848
31.25	2520.40041	0.60583	927.3630	682.3873	91.6940
	2519.79458	1.33393	1701.4443	774.0813	96.0099
	2518.46065	2.26712	2571.5355	870.0912	98.3971
31.75	2516.19353	3.41866	3540.0238	968.4883	98.5399
	2512.77487	+4.79471	4607.0520	1067.0282	—96.3079
	—2507.98016		—5770.3881	—1163.3361	

From the data of this table it is concluded by interpolation that, for the argument 31ᵈ.81828, the perturbations are

$$\delta V = -2513''.09\ , \qquad \frac{d.\delta r}{dt} = -0.0006348834$$

The unit of time for the latter is a day, and the linear unit the mean distance of *Titan*.

Let us suppose that the mass of *Titan* we have employed needs to be multiplied by a factor μ not likely to differ much from unity, and let it be granted that within these limits the perturbations may be considered as varying proportionally to μ. Then calling $\varDelta V$ the correction to the longitude of *Hyperion* through the change which ought to be made in the velocity attributed to it at opposition, the following equations ought to be satisfied:

$$178^\circ\ 39'\ 9''.75 + \varDelta V - 2513''.09\ \mu = 178^\circ\ 21'\ 41''.79$$

$$\frac{dr_0}{dt} - 0.0006348834\ \mu = 0$$

For convenience let it be supposed that the value of the daily mean motion, we have employed for the opposition, needs to be corrected by $60'' + \varDelta n$. Then the equations may be put in the linear form

$$26.1300\ \varDelta n - 2513''.09\ \mu + 2614''.21 = 0$$
$$-0.004579\ \varDelta n - 0.6348834\ \mu + 0.5682878 = 0$$

In the coefficients of $\varDelta n$ is included the effect of the change in e necessary to keep $a(1-e)$ constant. It will be seen there is no leaning towards indetermination in these equations. The solution gives

$$60'' + \varDelta n = +51''.7581$$
$$\log \mu = 9.9797984$$

The resulting mass of *Titan* is $m' = \frac{1}{4714}$, and the osculating elements of *Hyperion* at opposition are

$$\text{Daily } n = 60963''.23942$$
$$\log a = 0.0823532$$
$$e = 0.0994706$$

The mass of *Titan* here arrived at is quite different from any of the values published hitherto. Prof. NEWCOMB's value* will, however, be in substantial agreement if it is multiplied by 3; and it appears that this ought to be done, since the number 97.4, given as the sum of 72 values, in order to obtain the mean, through some inadvertance, doubtless, has been divided by 24 instead of 72. Prof. O. STONE has deduced a larger value.† But, since its publication, he has informed me that, after the rectification of an error committed in his investigation, he arrives at a value nearly the same with mine. With regard to the value of the mass obtained by M. F. TISSERAND‡ from the motion of the nodes of *Iapetus*, it appears difficult to explain the discrepancy, and I cannot here make the attempt.

From the data now in hand, without any further developments, it is possible to construct a table giving the inequality of the orbit longitude and the radius of *Hyperion* with the argument days after, or days yet to elapse before opposition with *Titan*. Such a table follows. It corresponds to an opposition radius of 192″.582, and to the mass of *Titan* as here found. When the argument is days yet to elapse before opposition, the signs given in the columns headed Inequality of Orbit Longitude must be reversed.

* *Astronomical Papers of the American Ephemeris*, Vol. III, p. 367.
† *Annals of Mathematics*, Vol. III, p. 161.
‡ *Annales de l'Observatoire de Toulouse*, Tom. I.

Arg.	Ineq. of Orb. Long.		Radius	
d	′	′	″	″
0.0	0.0	+115.1	192.58	+0.29
0.5	+115.1	111.5	192.87	0.85
1.0	226.6	104.4	193.72	1.37
1.5	331.0	94.4	195.09	1.86
2.0	425.4	81.8	196.95	2.27
2.5	507.2	67.5	199.22	2.60
3.0	574.7	52.2	201.82	2.87
3.5	+626.9	+36.1	204.69	+3.04
4.0	+663.0	+20.2	207.73	+3.14
4.5	683.2	+ 4.7	210.87	3.17
5.0	687.9	—10.3	214.04	3.11
5.5	677.6	24.0	217.15	3.01
6.0	653.6	36.7	220.16	2.84
6.5	616.9	48.1	223.00	2.62
7.0	568.8	58.2	225.62	2.37
7.5	+510.6	—66.9	227.99	+2.07
8.0	+443.7	—74.1	230.06	+1.76
8.5	369.6	80.1	231.82	1.42
9.0	289.5	84.5	233.24	1.06
9.5	205.0	87.6	234.30	0.68
10.0	117.4	89.5	234.98	+0.31
10.5	+ 27.9	89.8	235.29	—0.08
11.0	— 61.9	88.9	235.21	0.46
11.5	—150.8	—86.4	234.75	—0.83

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Arg.	Ineq. of Orb. Long.		Radius	
d	′	′	″	″
12.0	—237.2	—82.8	233.92	—1.20
12.5	320.0	77.8	232.72	1.56
13.0	397.8	71.2	231.16	1.88
13.5	469.0	63.4	229.28	2.19
14.0	532.4	54.2	227.09	2.47
14.5	586.6	43.6	224.62	2.70
15.0	630.2	31.6	221.92	2.90
15.5	661.8	18.6	219.02	3.04
16.0	680.4	— 4.3	215.98	3.12
16.5	684.7	+10.7	212.86	3.14
17.0	674.0	26.3	209.72	3.08
17.5	647.7	42.3	206.64	2.96
18.0	605.4	57.8	203.68	2.74
18.5	—547.6	+72.7	200.94	—2.45
19.0	—474.9	+86.1	198.49	—2.08
19.5	388.8	97.6	196.41	1.64
20.0	291.2	106.3	194.77	1.14
20.5	184.9	111.8	193.63	0.60
21.0	— 73.1	113.8	193.03	—0.03
21.5	+ 40.7	112.2	193.00	+0.52
22.0	152.9	107.2	193.52	1.08
22.5	260.1	98.7	194.60	1.58
23.0	358.8	87.7	196.18	2.03
23.5	446.5	74.5	198.21	2.40
24.0	521.0	59.9	200.61	2.71
24.5	580.9	44.2	203.32	2.94
25.0	625.1	28.4	206.26	3.07
25.5	+653.5	+12.7	209.33	+3.13
26.0	+666.2	— 2.5	212.46	+3.13
26.5	663.7	16.7	215.59	3.05
27.0	647.0	30.0	218.64	2.91
27.5	617.0	42.1	221.55	2.73
28.0	574.9	52.9	224.28	2.49
28.5	522.0	62.2	226.77	2.21
29.0	459.8	70.1	228.98	1.91
29.5	389.7	76.9	230.89	1.58
30.0	312.8	82.1	232.47	1.21
30.5	230.7	85.8	233.68	0.84
31.0	144.9	88.1	234.52	0.45
31.5	+ 56.8	—89.2	234.97	+0.06
32.0	— 32.4		235.03	

Washington, D.C., 1888 *June* 2.

OBSERVATIONS OF COMET 1888 a,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

BY PROF. E. FRISBY AND H. P. TUTTLE.

[Communicated by the Superintendent.]

1888 Washington M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″	s	″	
June 3 15 1 19.8	1	12 , 4	+1 54.32	+1 6.5	0 30 52.40	+40 46 9.9	n9.754	0.413	T
4 14 51 39.1	2	20 , 4	—2 29.50	—2 1.0	0 32 22.67	41 4 45.5	n9.753	0.396	F
5 12 0 45.4	3	12 , 4	+0 26.14	+2 30.5	0 33 40.19	41 20 54.3	n9.750	0.778	F
5 15 6 12.1	4	10 , 2	—2 36.37	+2 39.1	0 33 52.57	41 23 21.7	n9.750	0.390	T
7 11 42 45.8	5	20 , 4	—2 6.89	+3 41.6	0 36 32.63	41 56 33.2	n9.743	0.790	F
10 14 35 50.0	6	35 , 7	+1 30.63	+3 48.2	0 40 50.03	42 50 59.4	n9.774	0.404	T
11 14 23 24.0	7	30 , 6	+1 42.04	—5 23.4					T
12 11 32 11.5	8	19 , 4	—1 58.51	+3 8.7	0 43 14.38	43 22 39.4			F
12 11 32 11.5	9	20 , 4	—3 29.04	+2 12.1	0 43 14.52	43 22 33.3	n9.757	0.781	F
15 15 5 37.7	10	15 , 3	+7 7.15	—0 37.2	0 47 6.10	44 14 9.4	n9.747	0.200	T
16 15 2 5.9	11	20 , 4	+4 13.12	+6 34.1	0 48 16.05	+44 29 47.4	n9.748	0.189	T

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	0 28 58.04	+0.04	+40 45 15.7	—12.3	Weisse's Bessel O, 689
2	0 34 52.15	0.02	41 6 58.9	12.4	Weisse's Bessel O, 864
3	0 33 13.98	0.07	41 18 36.1	12.3	Weisse's Bessel O, 816–18
4	0 36 28.88	0.06	41 20 54.9	12.3	Weisse's Bessel O, 912
5	0 38 39.33	0.19	41 53 3.9	12.3	Weisse's Bessel O, 967
6	0 39 19.18	0.22	42 47 23.4	12.2	Weisse's Bessel O, 978
7					DM. 43° 147
8	0 45 12.63	0.26	43 19 42.8	12.1	Weisse's Bessel O, 1121
9	0 46 43.31	0.25	43 20 33.3	12.1	Weisse's Bessel O, 1156
10	0 39 58.54	0.41	44 14 58.6	12.0	Weisse's Bessel O, 998
11	0 44 2.51	+0.42	+44 23 25.3	—12.0	Weisse's Bessel O, 1088

WEISSE'S BESSEL O, 1121 seems to be in error by 1°. It has been changed here.

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FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *a*,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY WITH THE 10-INCH EQUATORIAL,

By F. P. LEAVENWORTH and H. V. GUMMERE.

1888 Haverford M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
June 3ᵈ 15ʰ 2ᵐ 45ˢ	1	4 , 2	+1ᵐ 55.02ˢ	+1′ 14.8″	0ʰ 30ᵐ 53.29ˢ	+40° 46′ 18.6″	n9.746	0.428	L
3 15 2 0	2	11 , 5	—0 37.32	—1 43.3	0 30 53.29	+40 46 18.3	n9.746	0.428	L
7 15 16 25	3	7 , 0	+0 5.78						G
7 15 16 25	4	7 , 3	—1 53.92	2 11.7	0 36 43.34	+41 50 39.8	n9.733	0.338	G
12 14 30 14	5	11 , 6	+0 30.51	2 15.8	0 43 24.67	+43 28 52.1	n9.771	0.412	L
12 14 39 36	6	11 , 4	+0 4.30	—0 45.6					L

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	0ʰ 28ᵐ 58.25ˢ	+0.02ˢ	+40° 45′ 16.0″	—12.2″	Weisse's Bessel 689
2	0 31 30.59	0.02	40 48 13.8	12.2	Weisse's Bessel 766
4	0 38 37.15	0.11	41 53 3.8	12.3	Weisse's Bessel 967
5	0 42 53.89	+0.27	+43 31 20.0	+12.1	Weisse's Bessel 1058

June 3. Nucleus about one magnitude fainter than comparison-star 2; scarcely distinguishable from tail. Tail composed of three parts, like prongs of a pitch-fork, but the outer ones much fainter and shorter than the central one. When united at the nucleus they seem to form a coma elongated at right angles to the central tail.

June 12. Nucleus about one magnitude fainter than comparison-star 6; scarcely distinguishable from tail. Central tail quite bright; northern one just visible; southern one doubtful. Comparison-stars 3 and 6 of the ninth magnitude.

THE VARIABLE STARS *T* AND *U MONOCEROTIS*, 1887,

By EDWIN F. SAWYER.

T Monocerotis.

This star was observed on sixty evenings, from 1886 November 19, to 1887 May 1. From these the following epochs of maxima and minima have been deduced, in Cambridge M.T., using the mean light-curve formed from the 1881–83 observations.

Observed Maxima.	Observed Minima.
1887 Jan. 9ᵈ 12ʰ 47ᵐ	1886 Dec. 3ᵈ 16ʰ 33ᵐ
Feb. 5 0 16	" 30 8 4
Mar. 5 23 28	1887 Jan. 25 10 39
" 31 11 54	Feb. 25 5 39
Apr. 28 8 8	Mar. 23 17 39
	Apr. 20 16 53

U Monocerotis.

Fifty-one observations were obtained on this star, extending from 1886 December 20, to 1887 May 9. From these observations six well determined maxima and minima have been obtained, as follows:

Maxima 1887 Jan. 15.0	Light =	27.1
Mar. 4.0		25.1
Apr. 28.0		27.8
Minima 1886 Dec. 28.5	Light =	8.3
1887 Feb. 18.5		15.0
Apr. 6.0		10.6

The interval between the first and second maximum = 48.0 days; and between the second and third maximum = 55 days. The interval between the first and second minimum = 52 days; and between the second and third mimimum = 46.5 days. The maxima were all bright ones. The first and third minima were rather faint ones, while the second was a bright one.

Cambridgeport, 1888 *May* 28.

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NOTE ON THE OCCULTATION OF *47 LIBRAE* BY *JUPITER*, 1888 JUNE 9.

The immersion was observed as follows; the emersion was not visible.

36-*inch Equatorial;* power 672; E. S. HOLDEN, Observer; J. E. KEELER, Recorder. Images, weight 2 (5 perfect; 1 very poor).

Chron. Negus 1667; $\Delta t = +1^m\ 15^s.0$.

At Chron. time, $14^h\ 10^m\ 0^s$, there was no black space between the star and the limb; the star then entered the limb and was seen bisected at chronometer time, $14^h\ 11^m\ 30^s.0$

The entire image of the star was seen, inside as well as outside of the limb, being easily distinguishable from the planet's surface by its brilliancy and peculiar color.

A dark semicircle, or band, about 1″ wide, on the following edge of the star's disc, I take to have been caused by the contrast of the star's light, and *Jupiter's*.

At Chron. time, $14^h\ 12^m\ 35^s.2$, the star was entirely inside of the limb, but was still visible.

The dark circle was no longer seen. For the next ten seconds or so, the star was alternately visible and invisible; the planet's limb was quite unsteady.

At Chron. time, $14^h\ 12^m\ 51^s.5$, the star was certainly gone, and it was not seen after $14^h\ 12^m\ 47^s \pm 2^s$. At $14^h\ 16^m$ I stopped looking for the star.

	h	m	s
For the instant of immersion I take	14	12	35.2
		+1	15.0
Standard Pacific mean time of immersion	14	13	50.2
Or Mt. Hamilton " "	14	7	15.9

I have asked Mr. BARNARD to add his observations to my own.

EDWARD S. HOLDEN.

Lick Observatory, 1888 *June* 11.

OBSERVATIONS.

The following observations of the disappearance of the $6^M.4$ star, *47 Librae*, in occultation by *Jupiter*, were made with the 12-inch equatorial; the aperture being reduced to 8.1 inches, as the images were too unsteady with full aperture. A magnifying power of 240 diameters was employed. I recorded the observations with the Dent Clock on the Fauth Chronograph; and also by calling time to Mr. C. B. HILL, who made the record on chronometer Negus, No. 1719, the correction to which, for local mean time, was $-7^m\ 46^s.0$.

Chronometer Times of Phenomena at Occultation,
1888 *June* 9.

$14^h\ 11^m$, star preceding *Jupiter's* limb by one of its own diameters.

$14^h\ 12^m$, star $\frac{3}{4}$ diameter preceding.

$14^h\ 13^m\ 11^s$, foll. edge of star in contact with preceding limb. (Recorded on chronograph at $19^h\ 24^m\ 6^s.9$.)

$14^h\ 14^m\ 23^s.2$, star partly on limb. (Chronograph $19^h\ 25^m\ 19^s.1$.)

$14^h\ 15^m\ 2^s.4$, star seen by glimpses. This was the last glimpse of the star, and three seconds later it had certainly disappeared. (Chronograph $19^h\ 25^m\ 57^s.9$, which I take to be the time of immersion.)

On a scale of 5 for perfect seeing, the images would have a weight of 2. The star was last seen with at least $\frac{3}{4}$ of its disc within the limb, but not entirely within; when it had encroached some distance on the limb it appeared small, round and bright, its disc being as clearly defined as that of a satellite entering transit.

The disappearance occurred *close south* of the parallel of the north edge of the north equatorial belt, the edge being more or less sinuous. No certain diminution of the light of the star was observed, except that due to the brighter background.

The correction to the Dent Clock, recording on chronograph, being $-1^m\ 54^s.67$ to local sidereal time at epoch of observation, the local sidereal time of immersion is $19^h\ 24^m\ 3^s.2$, and the corresponding Mt. Hamilton mean time is $14^h\ 7^m\ 15^s.9$.

E. E. BARNARD.

CONTENTS.

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THE

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THE EXTENSION OF THE LAW OF GRAVITATION TO STELLAR SYSTEMS,

By A. HALL.

After the discovery of the law of gravitation by NEWTON, and its brilliant confirmation in explaining the motions of the planets and satellites of our solar system, the question of its generalization and extension to the stellar universe would naturally be considered. IMMANUEL KANT was one of the earliest and most ingenious writers on this subject.* KANT begins his preface in the following manner: "I have chosen a subject which, both on account of its innate difficulty and also in regard to religion, may at first impress a great part of my readers with an unfavorable opinion. To discover the systematic arrangement which unites the great members of creation in its whole extent, even to infinity; to derive the formation of the heavenly bodies themselves, and the origin of their motions, from the primitive condition of nature by means of mechanical laws; are attempts that seem to surpass by far the powers of the human reason." The author, however, ventures boldly on this great problem, and KANT must be considered one of the founders of the nebular hypothesis. He concludes that the fixed stars are the centers of planetary systems in which the motions of the bodies are governed by the law of gravitation. A few years afterwards LAMBERT published speculations on the structure of the universe similar to those of KANT, though in some respects more complete in regard to the motions of the stars. In the years 1767 and 1784 the Rev. JOHN MICHELL published memoirs in the Transactions of the Royal Society of London on the relations of double and triple stars, and on clusters of stars. MICHELL's argument for the physical connection of such stars is based on the theory of probabilities, and he predicts that these stars will be found in motion around each other. Within a quarter of a century from the time it was made this remarkable prediction was verified by the observations and discoveries of Sir WILLIAM HERSCHEL.

* Allgemeine Naturgeschichte und Theorie des Himmels, oder Versuch von der Verfassung und dem mechanischen Ursprunge des ganzen Weltgebäudes nach Newtonischen Grundsätzen abgehandelt. Königsberg und Leipzig, bei Johann Friederich Petersen, 1755.

§2. The Newtonian law of gravitation follows from the laws of KEPLER, and these laws were deduced from observations of the planets. In the extension of the law of gravitation by analogy it has been assumed generally that this law governs the motions of the stars, without considering very carefully the condition of our knowledge of the motions of binary systems in the stellar world. In our solar system the law of gravitation has been firmly established by long series of observations of the planets and satellites. It appears also to have controlled the figures of the planets. The extension of such a law, therefore, to other systems may seem to be justified without further consideration. But the step is a great one, and it is well to examine the conditions under which it is taken. The laws of KEPLER are:

1. *The planets move in plane curves, and their radii vectores describe around the center of the sun areas that are proportional to the time.*
2. *The orbits of the planets are ellipses, the sun being in one of the foci.*
3. *The squares of the periodic times of the planets round the sun are as the cubes of the major axes.*

From these laws it follows that the force which governs the motion of a planet is situated in the focus of the ellipse at the center of the sun, and attracts the planet inversely as the square of the distance. This is shown in the *Mécanique Céleste*, Livre II, Chap. I. The result may be reached easily by means of a general proposition in central forces. Let R be the central force acting in the line joining the bodies, and take the plane of the orbit as the plane of xy. The equations of motion are,

$$\frac{d^2x}{dt^2} + R\frac{x}{r} = o: \quad \frac{d^2y}{dt^2} + R\frac{y}{r} = o$$

By cross multiplication we have

$$xdy - ydx = cdt$$

c being the constant of integration. For polar coordinates we have

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$$x = r\cos\theta: \qquad y = r\sin\theta$$
$$dx = \cos\theta\, dr - \sin\theta\, r\, d\theta$$
$$dy = \sin\theta\, dr + \cos\theta\, r\, d\theta$$
$$d^2x = \cos\theta\, d^2r - \sin\theta\, r\, d^2\theta - 2\sin\theta\, dr\, d\theta - \cos\theta\, r\, d\theta^2$$
$$d^2y = \sin\theta\, d^2r + \cos\theta\, r\, d^2\theta + 2\cos\theta\, dr\, d\theta - \sin\theta\, r\, d\theta^2$$

To find R in terms of the polar coordinates multiply the first equation of motion by $\cos\theta$, and the second by $\sin\theta$; then adding we have by means of the last values of d^2x and d^2y,

$$R = \frac{c^2}{r^3} - \frac{d^2r}{dt^2}$$

which is sometimes a useful form. From the values of dx and dy we evidently have $cdt = r^2\, d\theta$. In order to form a differential expression for the velocity multiply the first equation of motion by $2dx$, the second by $2dy$; then by addition

$$d.v^2 = -2Rdr = 2R.\frac{du}{u^2}$$

if $u = \frac{1}{r}$. But

$$v^2 = \frac{dr^2 + r^2d\theta^2}{dt^2} = c^2.\frac{dr^2 + r^2d\theta^2}{r^4d\theta^2} = c^2\left(u^2 + \frac{du^2}{d\theta^2}\right).$$

Taking $d\theta$ constant

$$d.v^2 = c^2\left(2udu + \frac{2d^2u.du}{d\theta^2}\right) = 2R.\frac{du}{u^2}$$

$$(1) \qquad R = c^2u^2\left(u + \frac{d^2u}{d\theta^2}\right).$$

If we denote now generally by X and Y the forces parallel to the axes of coordinates, the equations of motion are

$$\frac{d^2x}{dt^2} = X: \ \frac{d^2y}{dt^2} = Y$$

These equations give

$$x\frac{d^2y}{dt^2} - y\frac{d^2x}{dt^2} = xY - yX$$

By the first law of Kepler the area is proportional to the time, or

$$x\frac{dy}{dt} - y\frac{dx}{dt} = \text{constant},$$

so that

$$x\frac{d^2y}{dt^2} - y\frac{d^2x}{dt^2} = 0$$

or

$$X : Y :: x : y$$

and the direction of the force passes through the sun. By the second law the orbit is an ellipse, or

$$u = \frac{1+e\cos\theta}{a(1-e^2)}.$$

Since the force is central we may apply equation (1), and we have

$$R = c^2u^2\left\{\frac{-e\cos\theta}{a(1-e^2)} + \frac{1+e\cos\theta}{a(1-e^2)}\right\}$$

or

$$R = \frac{c^2}{a(1-e^2)}\cdot\frac{1}{r^2}$$

The central force therefore varies inversely as the square of the distance. Since c is the area described in the unit of time, if T be the periodic time of the planet, we have

$$cT = 2\pi\, a^2\sqrt{1-e^2}$$

and

$$R = 4\pi^2\,\frac{a^3}{T^2}\cdot\frac{1}{r^2}$$

By the third law the ratio $\frac{a^3}{T^2}$ is the same for each of the planets, and we may write

$$R = \frac{M}{r^2} \qquad (A)$$

where M has the same value for all the planets. This is the Newtonian law of gravitation which has been so completely verified by observing the motions of the bodies of our solar system during the last two centuries, and which also governs the motions of comets amound our sun.

§3. If we undertake to extend the preceding method to the orbits of double stars we shall find the proof incomplete. In this case observations furnish the coordinates of one star with respect to another, and the curve we see described is the projection of the real orbit on a plane perpendicular to the line of sight. If the real orbit be an ellipse, the apparent orbit will likewise be an ellipse, but the star assumed to be at rest, if it be at the focus of the real ellipse, will not also be at the focus of the apparent ellipse, unless the planes of the real and apparent orbits coincide. This condition complicates the determination of the orbit, and renders it difficult to establish by observation the truth of Kepler's second law for the motions of double stars. Since we can observe only the apparent orbits of the stars, and the fact that they describe equal areas in equal times, we may conclude that the force is central, but can not determine the law of force as in the case of planetary motion. This difficulty arises from the fact that the focus of the real orbit is not projected on the focus of the apparent orbit in which we observe the equal description of areas. Our inference of the Newtonian law must be from analogy. We know that an ellipse may be described by a body moving under this law, the central force being at the focus. We know also that an ellipse will be described if the force be at the center of the ellipse and the law of force is

$$R = Mr. \qquad (B)$$

In this case the periodic time is independent of the distance.

Are there other laws of force by which a conic would be described? This question was proposed by Bertrand in the *Comptes Rendus de l'Académie des Sciences*, 1887 April 9, and

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was immediately answered by DARBOUX and HALPHEN. Their solutions showed that a body moving in the plane of xy under the action of a central force would describe a conic when the force has the expression

$$(C) \qquad R = \frac{Mr}{(ax+by+c)^3}$$

or

$$(D) \qquad R = \frac{Mr}{(ax^2+bxy+cy^2)^{\frac{3}{2}}}$$

x and y being the rectangular coordinates of the body. These expressions are the general values of R.

The question in stated by BERTRAND as follows: "*Knowing that a material point under the action of a central force always describes a conic, it is required to find the expression of this force.*" The solution given by DARBOUX is very simple. Take the centre of force as origin; denote by u the reciprocal of the radius vector, and by θ the polar angle. The general equation of a conic can be written

$$u = a\cos\theta + b\sin\theta + \sqrt{A\cos 2\theta + B\sin 2\theta + H}$$

Hence

$$\frac{d^2u}{d\theta^2} = -a\cos\theta - b\sin\theta + \frac{-A^2-B^2-(A\cos 2\theta+B\sin 2\theta)^2-2H\,(A\cos 2\theta+B\sin 2\theta)}{(A\cos 2\theta+B\sin 2\theta+H)^{3/2}}$$

and by addition

$$u + \frac{d^2u}{d\theta^2} = \frac{H^2-A^2-B^2}{(A\cos 2\theta+B\sin 2\theta+H)^{\frac{3}{2}}}$$

Equation (1) gives therefore as the general expression for R,

$$(2) \qquad R = \frac{c^2\,(H^2-A^2-B^2)}{r^2\,(A\cos 2\theta+B\sin 2\theta+H)^{\frac{3}{2}}}$$

If we suppose $c^2(H^2-A^2-B^2) = M$, the value of R takes the form (D). If $A = B = 0$, we have the Newtonian law, and the force does not depend on θ. From the equation for u we may write

$$R = \frac{M}{r^2\left(\frac{1}{r} - a\cos\theta - b\cos\theta\right)^3}$$

By returning to rectangular coordinates, this gives the form (C). If a and b are zero, the expression gives $R = Mr$, which is the known result (B). *Despeyrous' Mécanique, Tome I, Note XII.* We see therefore that there are various laws under which a body would describe an ellipse round a center of force, and that among these the Newtonian law is one of the simplest. If we assume also that the force depends only on the distance, and not on the direction, — an assumption which our experience makes probable, — we have the forms (A) and (B); and finally, if we suppose the force to become zero at an infinite distance, we have the law of NEWTON.

§4. The earliest objector to the extension by analogy of the Newtonian law to stellar systems appears to have been AUGUSTE COMTE, the founder of the positive philosophy. At pp. 417–418 of his *Traité Philosophique d'Astronomie*, the author objects to such an extension on the ground that the observations are not sufficiently accurate to determine the true figure of the orbit, and especially that we cannot decide whether the principal star is at the focus or the center of the ellipse. On a preceding page COMTE had pointed out that an ellipse would be described with a force at the center and the law expressed by formula (B).

In the *Connaissance des Temps*, 1852, VILLARCEAU has discussed this question. He states his conclusion as follows:

"Although it results from the researches of astronomers that the movements observed in binary systems are not in any respect in opposition to the law of gravitation, we have not yet, however, the right to conclude that this law does in fact govern the motions of double-stars as it governs the planetary motions. The observations of double-stars cannot furnish an experimental proof of the universality of the law of gravitation, but only strong probabilities which are now beginning to be established."

We know that if we consider the motions of two bodies attracting each other the orbit must be in a plane. The observations of double-stars and the determination of their apparent orbits show that these bodies move in conic sections, and that the law of equal areas in equal times is observed. This kind of proof is cumulative, and will increase as time develops the motions of binary-stars, and as they are carefully observed. But it is exceedingly difficult to prove by observation that the principal star is in a focus of the ellipse of the real orbit, since we see only a single projection of this curve. The method that is followed by astronomers is to assume the Newtonian law of gravitation, and after the orbit is determined, compare the elements with observations, and in this way acquire a certain degree of probability that we have assumed the right law. VILLARCEAU shows that the proof of the law of NEWTON in our solar system and the proof of the universality of this law are of an essentially different nature. The first results from observation, and it is not necessary to invoke anything else than the principles of rational mechanics; the second cannot be established directly by observation, and we are compelled to recur to the theory of probability to justify its assumption. The probabilities in favor of the universality of the law of NEWTON may be very great in fact, but they do not constitute a proof offering the character of experimental certainty which clothes the law of NEWTON itself in our planetary system.

The weakness of the proof that the Newtonian law governs the motions of double-stars arises from two sources. In the first place the errors of observation have a large ratio to the quantities measured. This condition makes it difficult to

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compute the orbits with much accuracy, or we may satisfy the observations with very different elements. Hence there has been much computing of the orbits of double-stars where the results obtained are hardly worth the labor expended. When we find that a small change in the weights of the equations of condition produces great changes in the result, it is an indication that the data are insufficient, and in this case it is better to be satisfied with methods that are simple and are theoretically correct. The insufficiency in the data can only be removed by further observation. Since there is no theoretical difficulty in the way, the continuation of the observations of double-stars and the improvement of methods of observation will in time give the means for the accurate determination of their apparent orbits. The theoretical difficulty in proving the law of NEWTON for double-stars cannot be overcome. But we can increase the probability of the existence of this law by determining more orbits and those that are very differently situated. If the law prove satisfactory in all cases, we shall have a probability of its universality increasing with the progress of astronomy.

§5. There is another branch of astronomy connected with this question which in the future is destined to become of great interest. It is the part of sidereal astronomy that treats of the proper motions of the stars. We know already a large number of these motions, and more are continually coming to light. Since many of the large proper motions belong to stars of the fainter magnitudes, as our knowledge of the stars is extended, we shall doubtless find many more such examples. The following table contains some of the stars with the greater proper motions. The annual proper motion is denoted by μ, and the annual parallax by π. The values of the proper motions are well determined, but those of the parallaxes are sometimes doubtful. These latter have been taken from what seem the most probable determinations, except in those cases where no observations for parallax have been made. These, which are designated by a *, have been inferred from the table depending on magnitude given by C. A. F. PETERS, and from analogy. If we suppose the star to be moving at right angles to the line of sight the velocity in miles per second will be

$$v = [0.4671] \,.\, \frac{\mu}{\pi}$$

If we imagine a sphere with radius r described round the star the direction of motion may be towards any point of the surface of this sphere. Let φ be the inclination of a right line through the star to the plane passing through the star at right angles to the line of sight. The differential element of the spherical surface will be

$$d\sigma = r^2 \cos\varphi\, d\varphi\, d\psi,$$

where ψ is the angle of rotation around the line of sight. The integral with respect to ψ from o to 2π gives the circular element corresponding to φ, or $2\pi r^2 \cos\varphi d\varphi$. Since there are $4\pi r^2$ points on the sphere the mean inclination of the right line through the star to the plane will be

$$\varphi_0 = \frac{2\int_0^{\frac{\pi}{2}} 2\pi r^2 \varphi \cos\varphi \,.\, d\varphi}{4\pi r^2}$$

As we need only the direction we put r equal to unity and the result is

$$\varphi_0 = \Big[\varphi \sin\varphi + \cos\varphi\Big]_0^{\frac{\pi}{2}} = \frac{\pi}{2} - 1,$$

or $$\varphi_0 = 90^\circ - 57^\circ.3 = 32^\circ\, 42'$$

The probable velocity is therefore

$$v_1 = v \sec\varphi_0.$$

The last column of the table gives v_1.

Star	Mag.	μ	π	v	v_1
		$''$	$''$		
Groombridge 1830	7.0	7.05	0.10	207	246
Lacaille 9352	7.5	6.96	0.28	73	87
Gould 32416	8.5	6.08	0.10*	178	212
61 Cygni	5.5	5.22	0.35	44	52
Lalande 21185	7.5	4.75	0.50	28	33
ε Indi	4.0	4.68	0.22	62	74
Lalande 21258	8.5	4.40	0.27	48	57
o^2 Eridani	4.0	4.10	0.18	67	79
μ Cassiopææ	5.5	3.83	0.10	112	133
α Centauri	1.0	3.67	0.75	14	17
e Eridani	3.0	3.10	0.14	65	77
Groombridge 34	8.5	2.81	0.30	27	33
α Bootis	1.0	2.26	0.13	51	61
Bradley 3077	6.0	2.09	0.07	88	104
β Hydri	4.0	2.06	0.06*	101	120
σ Draconis	5.5	1.93	0.22	26	31
τ Ceti	3.5	1.90	0.06*	93	110
ε Pavonis	4.0	1.63	0.05*	96	114
61 Virginis	5.0	1.45	0.05*	85	101
γ Serpentis	3.5	1.32	0.06*	64	77
85 Pegasi	6.0	1.30	0.05	76	91

The velocities of the planets of our system which are nearest the sun are, in the same units, Mercury 29.5; Venus 21.6; Earth 18.4; and Mars 15.0.

Although the parallax of the star introduces considerable uncertainty into the velocities given in the table, yet we already know enough to be sure that these velocities are very great. Some of them are comparable to that of a comet in close proximity to our sun. But in most cases there is no visible object near the one in motion to which we can ascribe an attractive force, acting according to the Newtonian law, which would produce the velocity observed unless we assume enormous masses. We are here on speculative ground. The further investigation and the explanation of this question remain for the future, but our present knowledge should make us cautious about general deductions. The law of NEWTON is one of the greatest generalizations of science; and yet it seems to me better, and certainly far safer, to await further knowledge before we proceed as KANT has done to construct the universe according to this law.

1888 *July* 2.

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OBSERVATIONS ON THE VARIABLE β LYRAE, 6758

By WILLIAM MAXWELL REED.

I beg to submit the results of the following series of seventy-five observations made on this star during the latter half of 1887.

The comparisons were made by ARGELANDER's method, and reduced in the usual manner by means of the light-scale of comparison-stars hereafter given. The resulting values are presented in the following table, in which, against each date expressed in decimals of a day, Cambridge M.T., are placed my values of the light of the star in the column *R*.

OBSERVATIONS.

1887 Camb. M.T.	*R*	1887 Camb. M.T.	*R*	1887 Camb. M.T.	*R*	1887 Camb. M.T.	*R*
May 1.38 d	+13.6	June 14.43 d	+14.7	Aug. 8.48 d	+22.2	Oct. 15.41 d	+17.0
9.39	16.4	15.43	16.9	9.37	15.0	19.43	18.4
10.37	6.9	25.45	13.3	10.43	3.9	Nov. 5.41	21.2
12.42	1.8	26.39	14.0	12.38	17.4	7.24	18.9
13.40	9.0	29.45	15.5	13.39	16.9	8.26	8.7
14.42	14.0	30.46	18.4	16.39	15.3	16.26	10.8
15.37	12.0	July 1.46	17.9	18.38	17.0	18.28	19.4
16.40	13.0	4.41	11.7	27.53	18.4	22.28	5.9
19.42	11.0	7.46	18.9	Sept. 1.43	19.2	27.22	11.8
20.45	13.0	12.39	17.9	4.45	15.5	32.24	18.4
21.44	13.0	13.38	17.9	14.45	22.2	31.25	19.4
22.38	13.0	16.38	3.75	16.42	17.4	Dec. 3.28	16.0
23.42	17.7	19.37	18.9	17.38	17.4	6.23	12.8
25.43	+ 2.2	20.38	17.0	18.40	6.2	14.22	22.2
June 7.39	— 1.3	25.37	19.9	19.34	5.9	16.24	20.2
10.41	+18.4	27.37	16.5	20.30	17.0	18.27	12.5
11.44	17.0	28.41	2.1	23.40	19.2	22.28	17.2
12.43	15.5	30.36	15.7	Oct. 12.42	+18.2	24.25	+16.1
13.44	+11.3	Aug. 7.36	+17.9				

The times of minimum have been deduced by reference to the light-curves of ARGELANDER and SCHÖNFELD, independently. Thus from the following values of the light-scale:

	A	*S*	*R*
γ	12.7	15.0	22.2
ξ	10.3	10.3	13.6
θ			12.4
o	7.6	7.8	10.0
ζ	3.4	2.9	5.6
δ			3.9
κ	2.6	1.2	0.8

I found, by a graphical process, the relations

$$A = 0.30 + 0.69R$$
$$S = 0.70 + 0.55R$$

by means of which I determined the values of *S* and *A* in the following table.

These values, in conjunction with the use of ARGELANDER's and SCHÖNFELD's light-curves, and by the application of ARGELANDER's method, result in the following times of principal minima:

MINIMA, CAMBRIDGE M.T.

Epoch	Computed Minima	Observed Minima. *A*	*A—C*	*S*	*S—C*	Wt.
914	1887 April 28.972	April 30.81 d	+1.34 d	d	d	½
915	May 11.891	May 12.27	+0.38	May 12.26	+0.37	1
916	24.799	25.26	+0.46	25.43	+0.63	½
917	June 6.713	June 7.39	+0.68	June 7.39	+0.68	½
919	July 2.541	July 3.68	+1.14	July 3.42	+0.88	½
920	15.454	15.81	+0.36	15.45	+0.00	½
921	28.368	28.85	+0.48	29.08	+0.71	1
922	Aug. 10.283	Aug. 10.20	—0.08	Aug. 10.46	+0.18	1
924	Sept. 5.110	Sept. 5.78	+0.67	Sept. 6.04	+0.93	½
925	18.024	18.44	+0.42	18.60	+0.58	1
927	Oct. 13.851	Oct. 14.16	+0.32	Oct. 13.39	+0.46	1
929	Nov. 8.679	Nov. 9.36	+0.68	Nov. 9.09	+0.41	1
930	21.593	21.74	+0.16	21.74	+0.16	½
931	Dec. 4.506	Dec. 5.13	+0.62	Dec. 5.13	+0.62	½
932	17.419	17.34	—0.08	17.24	—0.18	½

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The columns $A-C$ and $S-C$, contain the comparisons with the computed minima, according to ARGELANDER's elements of this star. The means of the residuals give, for the mean epoch 923, the corrections to these elements $+0^d.474$ and $+0^d.467$, according to the two curves, respectively, with the corresponding probable errors of $\pm 0^d.08$ and of $\pm 0^d.05$.

The mean of these indicated corrections is

$$+0^d.4705 = +11^h\ 17^m.5.$$

SCHÖNFELD found, in 1865 and 1870, the corrections,

for epoch 291 $+0^h\ 53^m.2$ $\pm 17^m.49$
for epoch 450 $+2^h\ 53^m.6$ $\pm 21^m.30$

From the foregoing it appears that the deviation of the assumed elements is rapidly increasing. Assuming the correction of ARGELANDER's principal epoch to be zero, the above data would furnish three equations, from which to find new values for the period and the terms depending on the second and third powers of the time. But, as it is proposed to continue observations upon the star the coming season, I defer making a definitive computation, remarking merely that, using somewhat different corrections from the above, I found, provisionally, the following corrected values of the elements:

$$1855 \text{ Jan. } 6^d\ 14^h\ 38^m.0 \text{ Paris M.T. } +12^d\ 21^h\ 46^m\ 58^s.3\ E + 0^s.4217\ E^2 - 0^s.0000700\ E^3$$

which are probably very near the truth.

Cambridge, 1888 *July* 29.

DEFINITIVE DISCUSSION OF OBSERVATIONS OF *U OPHIUCHI*,

By EDWIN F. SAWYER.

During the past few years I have published, on various occasions, the results of my observations upon this star. These results, from the nature of the case, were provisional. The accumulation of observations is now sufficiently abundant, however, to warrant the undertaking of a systematic reduction of the whole series, which comprise 1135 comparisons, or 527 observations on 57 nights, each observation being thus based on an average of 2.1 comparisons. The results of this definitive discussion are here given. The light-scale was formed in the ordinary manner, using all the observations from 1881 to 1887 inclusive. After adjustment of small outstanding differences between the independent equations, the following light-scale was adopted:

	Light		Light
$a =$	13.0	$e =$	5.0
$b =$	8.9	$f =$	—1.5
$d =$	8.5	$g =$	—1.8

The places for these stars will be found on page 137, Vol. VII, of the Journal.

With this scale the original observations were reduced anew. The times of the individual observations were compared with the computed times of the nearest minima, employing for this purpose the definitive elements given by CHANDLER on page 139, Vol. VII. The data were then assembled by graphical processes, and successive approximations, to form a mean adjusted light-curve. The intervals between points of equal brightness were bisected, and an intersecting curve drawn through the middle points. The correction to the computed zero of minimum thus indicated was $-10^m.0$. The readings of the light-curve, reckoning from the new zero, give the following light-table:

BEFORE MINIMUM.				AFTER MINIMUM.			
h m		h m		h m		h m	
2 0	8.35	0 55	4.68	0 5	1.88	1 15	5.23
1 55	8.25	50	4.11	10	1.93	20	5.59
1 50	8.09	45	3.65	15	2.03	25	5.99
1 45	7.95	40	3.29	20	2.16	30	6.35
40	7.76	35	2.90	25	2.31	35	6.66
35	7.53	30	2.62	30	2.41	40	6.93
30	7.27	25	2.37	35	2.49	45	7.13
25	6.95	20	2.17	40	2.66	50	7.34
20	6.63	15	2.08	45	2.90	55	7.52
15	6.25	10	1.97	50	3.23	2 0	7.68
10	5.88	5	1.90	55	3.65	5	7.86
5	5.49	0	1.86	1 0	4.11	10	8.01
1 0	5.07			5	4.54	15	8.17
				10	4.88	20	8.31

In order to compare the light-curve with that found by Mr. CHANDLER from his observations (p. 138, Vol. VII), I have deemed it of sufficient interest to prepare the accompanying representation of both. They are superposed without any attempt to adjust the scales, except to add 0.4 of a step to my values, which secures a sufficiently good correspondence to admit a comparison to be made. The decrease of light, according to my observations, appears to be slightly more rapid; the curve about minimum is somewhat flatter; and the retardation after minimum, spoken of by Mr. CHANDLER (p. 138), is independently shown, at the same point after minimum, but is decidedly less marked.

The times of minimum for the whole series were now calculated anew by means of the final light-curve, by ARGELANDER's method, employing the weights described on page 132; with the appended results:

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Light Curve of U Ophiuchi.

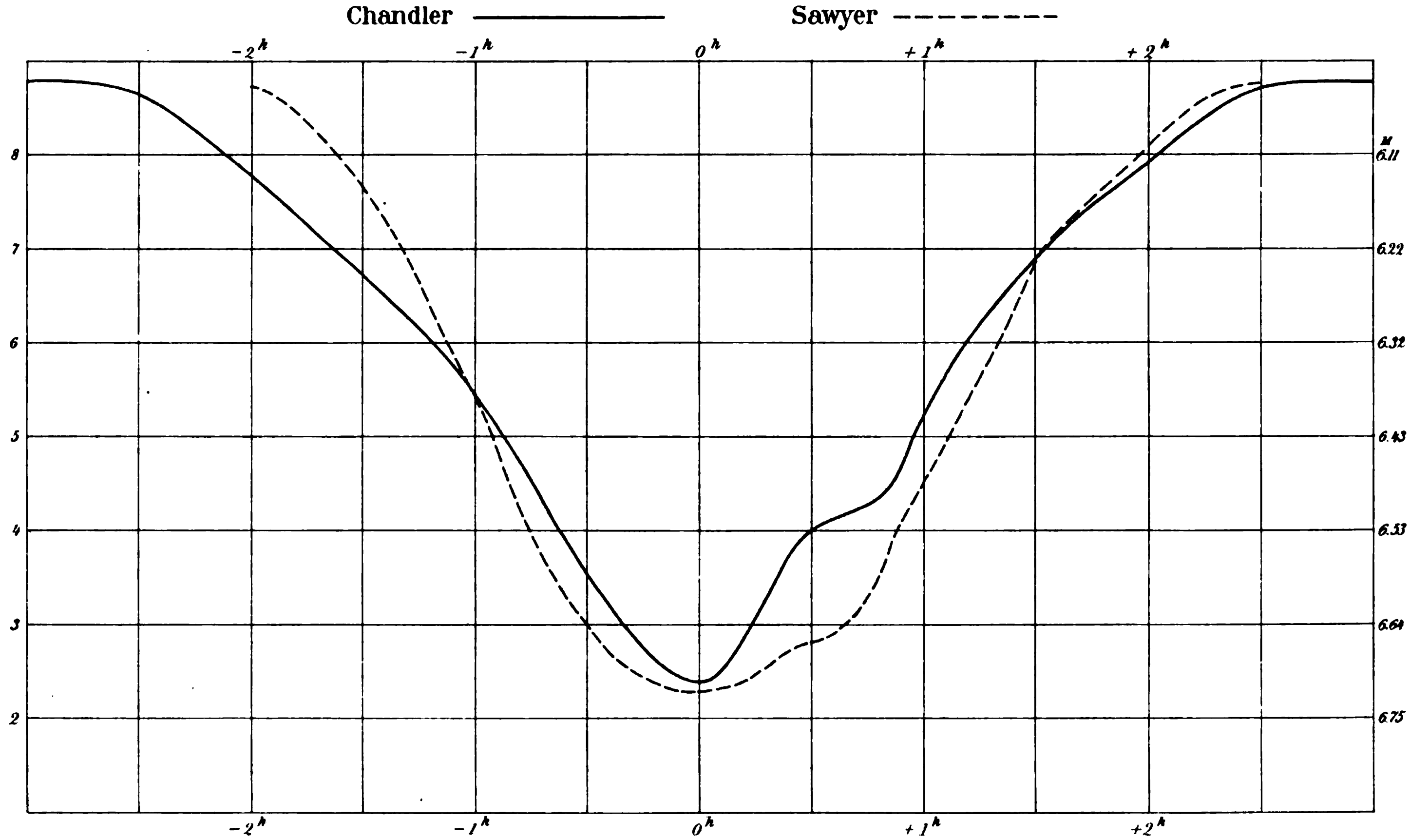

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TABLE OF OBSERVED MINIMA.

Epoch	Observed Minimum Camb. M.T.	Light Equat.	Wt.	O—C	Epoch	Observed Minimum Camb. M.T.	Light Equat.	Wt.	O—C
	d h m	m		m		d h m	m		m
372	1882 May 25 10 28.1	+7.5	2	+ 5.0	1302	1884 July 13 9 27.7	+6.4	3	— 6.1
403	June 20 10 32.0	+7.5	2	+10.5	1320	28 11 30.5	+5.1	1	—23.8
422	July 6 8 40.2	+6.8	3	— 8.0	1383	Sept. 19 8 5.9	—1.3	4	+ 1.9
428	11 9 44.4	+6.5	1	+ 9.7	1408	Oct. 10 7 7.9	—3.8	2	—10.7
434	16 10 18.8	+6.1	3	— 2.5	1699	1885 June 11 8 31.6	+7.6	2	+ 8.8
446	26 12 5.5	+5.2	1	+11.1	1736	July 12 9 1.2	+6.4	4	— 6.9
459	Aug. 6 9 33.8	+4.1	4	— 1.5	1798	Sept. 2 9 10.7	+0.8	4	+ 0.6
465	11 10 26.6	+3.5	4	+ 4.3	1842	Oct. 9 6 49.5	—3.7	3	— 3.0
490	Sept. 1 9 36.7	+1.0	5	— 0.2	2157	1886 June 30 10 52.7	+7.2	3	— 9.2
503	12 7 14.8	—0.4	3	— 3.5	2182	July 21 10 17.5	+5.7	2	+ 3.1
812	1883 May 29 10 37.2	+7.5	5	— 9.2	2220	Aug. 22 7 7.6	+2.2	1	— 2.0
843	June 24 10 44.5	+7.4	5	— 0.2	2226	27 8 24.0	+1.6	½	+27.6
862	July 10 9 9.0	+6.6	4	— 2.6	2257	Sept. 22 7 55.8	—1.7	5	— 1.9
880	25 11 12.3	+5.4	4	—19.0	2270	Oct. 3 5 28.7	—3.0	½	—10.0
892	Aug. 4 12 51.4	+4.3	4	—13.1	2276	8 6 50.1	—3.6	2	+24.6
893	5 9 5.0	+4.2	5	— 7.3	2579	1887 June 19 9 20.7	+7.5	1	+20.3
899	10 9 42.9	+3.7	5	—16.1	2585	24 9 53.5	+7.4	1	+ 6.9
918	26 8 5.0	+1.7	4	—22.0	2616	July 20 9 34.8	+5.8	2	—11.4
924	31 9 0.3	+1.1	5	—13.5	2647	Aug. 15 9 49.9	+3.1	3	+ 3.1
930	Sept. 5 9 40.7	+0.5	5	—19.9	2672	Sept. 5 8 55.2	+0.5	5	— 6.1
949	21 8 28.3	—1.6	5	— 0.4	2678	10 9 38.2	—0.2	3	— 9.9
1271	1884 June 17 9 29.4	+7.5	5	— 5.0	2722	Oct. 17 7 26.8	—4.6	5	+ 5.6
1277	22 10 30.9	+7.4	2	+10.4	2753	Nov. 12 7 30.5	—6.7	1	+ 1.1

The comparison in column O—C is with Mr. CHANDLER's definitive elements. The yearly means, using the indicated weights, are:

Mean Epoch	O—C Definitive Elements	O—C Original Elements	Wt.
	m	m	
442	+ 0.7	0.0	28
891	—10.9	—13.5	51
1327	— 3.5	— 9.3	17
1769	— 1.3	—11.8	13
2227	+ 1.8	—14.4	14
2656	— 0.8	—26.8	21
1552	— 4.2	—12.2	144

I have added the difference from Mr. CHANDLER's original elements, which differ from his definitive elements only by the term depending on the square of the time, as shown on page 133. The results appear to confirm the existence of that term. The mean correction by the definitive elements, it will be seen, is —4^m.2, corresponding to the mean epoch 1552. This is scarcely half the value independently found graphically from the light-curve above, but it should be entitled to the preference.

In regard to the prevalence of the minus sign in the values (O—C) for 1883, I have already mentioned (*Astron. Nach.* CVIII, 409), a circumstance which seems to justify the suspicion that the results for that year may have been subject to an anomalous influence. Further remarks on the subject will be found on page 132 of Vol. VII of *Astronomical Journal*. It may be safer to omit the results for this year, therefore, in taking the mean: doing this we find the correction to the definitive elements to be only —0^m.5, in place of —4^m.2, just given.

Cambridgeport, 1888 *July* 6.

DETERMINATION OF THE ORBIT OF COMET 1887 IV; ADDENDUM,

BY FRANK MULLER.

The following observations were omitted in preparing the copy for the printer, and the omission was not discovered until too late to insert them in their proper place on p. 49.

I take this opportunity of acknowledging the receipt, since the completion of my work, of observations of the comet made at Vienna, Nicolajew, and Cincinnati. I regret the omission of these observations, and had hoped that my request published in the *Astronomische Nachrichten* of June 8 would have insured their earlier publication.

1888 *July* 14.

Algiers. TRÉPIED. 50 cm. *A.N.* 2788; *B.A.*, Oct., Nov.

Gr. M.T.	α	δ	Δα	Δδ	*
June	h m s	° ′ ″	s	″	
9.37068	16 4 5.95	—11 7 24.4	+0.47	— 8.6	59
10.43735	6 27.64	10 17 34.7	+0.83	11.6	62
15.42039	17 35.50	6 32 19.0	+0.66	5.7	72
16.39474	19 47.13	5 50 22.5	+0.63	11.9	86
20.39425	28 48.44	3 6 41.0	—0.03	21.2	94
22.45514	33 27.28	1 48 16.9	+0.16	13.3	101
23.38888	16 35 34.74	— 1 16 37.4	(—0.02	—152.0)	107

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NOTE ON COMET 1888 *a*,

BY LEWIS BOSS.

By a ring-micrometer observation of comet 1888 *a* which I obtained July 28, at $15^h.9$ corrected Greenwich time, the correction to the ephemeris in No. 173 (*A.J.*) was

$$\Delta\alpha = -10^s.4\,;\ \Delta\delta = +13''.$$

Though the comet was then extremely faint, and merely a streak of nebulosity, without a well defined head, I consider it possible that it may be followed perhaps beyond August 14, the date with which the ephemeris in No. 173 closes. I therefore enclose an extension of that ephemeris, computed at my request by Prof. C. W. CROCKETT, of Troy, N.Y., who is temporarily pursuing his studies at this Observatory.

EPHEMERIS OF COMET 1888 *a*,

CONTINUED FROM No. 173, BY C. W. CROCKETT.

1888	App. α	App. δ	log r	log Δ	1888	App. α	App. δ	log r	log Δ
	h m s	° ′ ″				h m s	° ′ ″		
Aug. 14.5	0 54 15.4	+54 54 31	0.41244	0.34480	Sept. 4.5	0 25 19.3	+54 59 21		
15.5	53 10.1	54 58 22			5.5	23 43.9	54 55 14	0.45678	0.35610
16.5	52 2.7	55 1 54	0.41673	0.34559	6.5	22 8.1	54 50 43		
17.5	50 53.2	55 5 6			7.5	20 32.0	54 45 48	0.46053	0.35758
18.5	49 41.6	55 7 57	0.42097	0.34640	8.5	18 55.8	54 40 27		
19.5	48 28.0	55 10 27			9.5	17 19.5	54 34 42	0.46424	0.35916
20.5	47 12.5	55 12 37	0.42515	0.34724	10.5	15 43.2	54 28 32		
21.5	45 55.1	55 14 25			11.5	14 7.2	54 21 59	0.46790	0.36085
22.5	44 35.9	55 15 51	0.42927	0.34813	12.5	12 31.4	54 15 00		
23.5	43 14.9	55 16 55			13.5	10 56.0	54 7 38	0.47152	0.36266
24.5	41 52.3	55 17 37	0.43335	0.34906	14.5	9 21.1	53 59 53		
25.5	40 28.2	55 17 56			15.5	7 46.8	53 51 44	0.47510	0.36460
26.5	39 2.5	55 17 52	0.43737	0.35005	16.5	6 13.1	53 43 12		
27.5	37 35.4	55 17 25			17.5	4 40.2	53 34 17	0.47864	0.36665
28.5	36 7.0	55 16 34	0.44135	0.35110	18.5	3 8.2	53 25 1		
29.5	34 37.4	55 15 19			19.5	1 37.1	53 15 23	0.48214	0.36884
30.5	33 6.6	55 13 40	0.44528	0.35223	20.5	0 0 7.1	53 5 23		
31.5	31 34.8	55 11 38			21.5	23 58 38.2	52 55 2	0.48560	0.37116
Sept. 1.5	30 2.1	55 9 10	0.44916	0.35343	22.5	23 57 10.4	52 44 20		
2.5	28 28.5	55 6 19			23.5	23 55 43.9	+52 33 19	0.48903	0.37362
3.5	0 26 54.2	+55 3 2	0.45300	0.35472					

Light: Aug. 14.5, 0.019; Sept. 23.5, 0.012.

ENCKE'S COMET, 1888 *b*,

A *Science Observer* dispatch received August 5, from Capetown, through KIEL, announces the finding of ENCKE's comet in the following position:

$$1888 \text{ August } 3.2571 \text{ Greenwich M.T.} \qquad \alpha = 12^h\ 12^m\ 53^s.5 \qquad \delta = -17^\circ\ 27'\ 19''$$

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 178.

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MICROMETER OBSERVATIONS OF THE SATELLITES OF *MARS*,

BY JAMES E. KEELER, ASTRONOMER OF THE LICK OBSERVATORY.

[Communicated by the Director.]

The observations recorded below were made with the 36-inch equatorial during the opposition of *Mars* in 1888, when the Observatory was still in the hands of the LICK Trustees, on such occasions as the work of construction would allow. The telescope had been erected but a few months before, no adjustments had been made, and it was used in the condition in which it had been left by the builders.* The machinery for operating the hydraulic floor was being put into place, and it was only when the floor could be left at night near the top of its range that observations were possible. Under these circumstances a systematic arrangement of the observations, or the following of any prearranged method, was entirely out of the question.

The first opportunity which occurred for looking for the satellites was on the night of April 5, when they were easily seen. On the 9th, a magnificent night, they were bright objects, being easily visible in the same field with *Mars*, even without an occulting bar to hide the planet. On this night I made a few measurements of position angles, and searched very carefully for other satellites, but without success. After this, observations were made at irregular intervals until April 28, when they had to be entirely discontinued, as the work on the elevating floor prevented any further use of the telescope.

After the completion of the Observatory and its transfer to the state, the satellites had become too faint for satisfactory observations. *Phobos* was fairly well seen on June 4. Both satellites were seen on June 7, but hardly well enough for measurement. *Deimos* was seen with difficulty on June 17 by Professor HOLDEN, Mr. BARNARD and myself, and although it might have been possible to follow the satellites for some time further, measurement was out of the question, and they were no longer looked for. *Phobos* was seen on July 18 by Professor HOLDEN, while examining the surface of *Mars*.

The micrometer used in these measurements is a large and perfect instrument by FAUTH & Co. It has a position circle 11 inches in diameter, read by two verniers to 0°.01, but only one of the verniers was read, as the eccentricity is quite inappreciable. The box contains three fixed and two movable threads, illuminated at night by a small incandescent electric lamp. No illumination was required for measurements of *Phobos*, as that satellite is always seen upon the sufficiently bright background of the secondary spectrum of *Mars*, but the light had to be used for *Deimos* when more than two diameters of the planet distant, and proved to be entirely satisfactory.

An occulting bar, consisting of a thin slip of glass one-tenth of an inch wide, lightly smoked on the side toward the object-glass, was placed across the field of the eye-piece, with the smoked surface just clear of the micrometer wires. Through this bar the planet could be seen very distinctly, while the satellites appeared in the clear space outside. The width of the bar in angular measure was 30″.5, or about twice the apparent diameter of *Mars*.

One of the movable threads was used in the measurement of position angles.

The observations of April 9 were made with a small micrometer belonging to the 12-inch equatorial, provided with an occulting bar but no threads, the edge of the bar being placed by estimation at right-angles to the line joining the satellite and center of the planet. These observations appear to be nearly equal in accuracy to those made with the more complete apparatus afterward used, and have consequently been included in the record. The power used in all observations was about 600.

A provisional value of the micrometer screw, sufficiently accurate for the reduction of these observations, was determined by transits of polar stars over the three fixed threads. The results are given below.

* Subsequent determinations of the position of the polar axis show that at this time it was 5′ too low, and 20ˢ west of north.

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June 20, 1888.	9 transits of	β *Urs. Min.*	(weight 3),	1 rev.	=	9″.908
21, "	10 "	ζ *Urs. Min.*	" 4		=	9.883
21, "	4 "	ϵ *Urs. Min.*	" 3		=	9.898
July 2, "	13 "	ζ *Urs. Min.*	" 5		=	9.910
2, "	6 "	ϵ *Urs. Min.*	" 5		=	9.906

Mean by weights, 1 rev. = 9″.902.

Both telescope tube and micrometer screw being of steel, there is no correction for temperature large enough to affect these measurements.

The brightness of *Mars* at different times is given in the following table, the unit being the brightness at mean opposition as defined by Zöllner, that is, an opposition when both *Mars* and the earth are at their mean distances from the sun, and in a straight line passing through the sun's center. In applying the correction for phase, the diminution of brightness is assumed to be represented simply by the ratio of the unilluminated portion to the total area of the disc.

Brightness of *Mars* at Different Times.

Date	Remarks	Brightness
1877, Aug. 11	Satellites discovered by Prof. Hall, at Washington	1.91
1877, Sept. 5	Opposition	2.31
1879, Nov. 12	Opposition	1.22
1888, Apr. 5	Satellites first observed at Lick Observatory	0.62
1888, Apr. 10	Opposition	0.66
1888, June 4	*Phobos* seen at Lick Observatory	0.40
1888, June 7	Both satellites seen at Lick Observatory	0.38
1888, June 19	*Deimos* last seen at Lick Observatory	0.32
1888, July 18	*Phobos* last seen at Lick Observatory	0.22
1890, May 27	Opposition	1.15

An interesting phenomenon, but one of which only a few rough observations could be made, is the variation in the relative brightness of the satellites in different parts of their orbits. Professor Pickering* makes *Deimos* one-half magnitude brighter on the following than on the preceding side of *Mars*, and the few estimates which I have made are roughly in agreement with his measurements.

The markings on the surface of *Mars* were beautifully seen during the month of April, but I could make no drawings without neglecting the work already begun, and as much better opportunities in every respect will be afforded by the oppositions of 1890 and 1892, I made no observations worthy of preservation.

Micrometric Observations.†

April 9, 1888.

Night still and clear; satellites very distinct and bright, even without hiding the planet. They were also well seen with the 12-inch equatorial.

The time was recorded by chronometer Negus 1719 to the nearest 5ˢ. (Pacific Standard Time is eight hours slower than Greenwich Mean Time.)

Position Angles of *Phobos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
13 21 30	107.9	Clark Micrometer used this night.
13 24 10	110.4	
13 26 0	111.1	
13 27 30	110.8	
13 31 5	114.4	
13 33 10	113.9	
13 36 30	116.7	
13 47 30	119.6	
14 6 30	127.3	
14 8 0	126.1	

$13^h 45^m$. Parallel = 229°.5 (2 obs.)

April 10, 1888.

Night warm; considerable wind blowing. Definition worse than on the 9th and satellites not nearly so distinct. The images were unsteady and measures difficult.

After midnight the definition improved somewhat, as the wind died away.

* *Annals of Harvard College Observatory* XI, part I, Appendix F.

† As this is the first work ever done with the great telescope, the results have been given in greater detail than absolutely necessary.

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POSITION ANGLES OF *Phobos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
13 3 0	124.66	Fauth Micrometer used on this and all succeeding nights
13 7 15	126.08	
13 9 0	126.66	
13 12 0	128.18	
13 14 20	128.93	
13 17 0	129.18	
13 19 20	130.06	

13h 29m. Parallel = 289°.36.(3 obs.)

DIAMETER OF *Mars*.

Pacific Time	Diameter	Remarks
h m	"	
13 37	15.56	Measured through the occulting bar. Edges of disc undulating considerably
	15.60	
	15.69	

DISTANCE OF *Phobos*.

Pacific Time	Distance	Remarks
h m s	"	
13 44 50	19.43	From center of *Mars*
13 58 40	17.96	

DISTANCE OF *Deimos*.

Pacific Time	Distance	Remarks
h m s	"	
14 7 45	34.40	From center of *Mars*
14 22 0	36.64	

POSITION ANGLES OF *Deimos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
14 11 0	99.01	
14 13 20	97.98	
14 17 0	99.56	

April 11, 1888.

Night almost calm, with very slight breeze from the south. Definition excellent. The sky was slightly hazy, but the satellites were bright enough to be seen without the occulting bar, in the same field with the planet. The bar had been resmoked to a somewhat lighter shade.

POSITION ANGLES OF *Phobos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
11 27 25	115.29	All these measures seemed to be good
11 31 55	116.88	
11 34 50	118.48	
11 37 25	118.17	
11 40 15	119.16	
11 43 35	120.30	

POSITION ANGLES OF *Phobos*. — *Continued*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
11 46 40	121.40	
12 1 35	125.94	
12 4 40	127.52	
12 6 25	127.76	
12 8 40	128.34	
12 12 0	129.37	
12 17 15	131.01	
12 19 0	131.16	

11h 53m. Parallel = 289°.29 (3 obs.)

DISTANCE OF *Phobos*.

Pacific Time	Distance	Remarks
h m s	"	
12 25 0	28.87	From W limb of *Mars*
12 29 15	11.91	" E " "
12 34 30	28.02	" W " "
12 37 0	11.38	" E " "

DISTANCE OF *Deimos*.

Pacific Time	Distance	Remarks
h m s	"	
12 42 40	46.86	To center of *Mars*. Wire on *Deimos* dim

POSITION ANGLE OF LINE JOINING *Deimos* AND *Phobos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
12 52 40	140.52	

POSITION ANGLES OF *Phobos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
12 55 50	142.59	
12 58 0	143.37	
13 0 40	145.29	
13 4 40	146.86	
13 7 30	149.93	
13 11 40	153.25	Very close to limb
13 17 45	194.30	Position-angle of tang. to E limb of *Mars* passing through satellite
13 22 20	197.96	

13h 35m. Parallel = 289°.39 (3 obs.)

POSITION ANGLES OF *Deimos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
13 49 25	328.66	
13 54 25	328.56	
13 57 30	329.38	
14 1 40	330.97	
14 5 50	331.07	
14 8 25	331.38	
14 12 45	331.99	

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DISTANCE OF *Deimos.*

Pacific Time	Distance	Remarks
h m s	"	
14 20 25	36.04	From center of *Mars*. Wire dim
14 24 5	36.33	at both observations

14^h 33^m. Parallel = 289°.38 (3 obs.)
Temp. = 60° Fah.

April 12, 1888.

Night nearly calm, very light breeze from N.W. Definition good, about the same as last night and observations of about the same weight.

In measurements of *Deimos* the bright wire illumination by electric lamp was used for the first time.

DISTANCE OF *Phobos.*

Pacific Time	Distance	Remarks
h m s	"	
11 15 10	20.72	All from center of *Mars*
11 17 45	20.41	
11 19 25	20.46	
11 23 20	19.79	
11 25 45	19.72	
11 28 5	19.84	
11 29 50	19.46	
11 31 15	19.42	
11 33 25	19.25	
11 39 25	18.61	From center
11 42 45	10.58	From E limb of *Mars*
11 44 25	26.34	" W " "
11 47 5	10.08	" E " "
11 49 50	25.00	" W " "

12^h 9^m. Parallel = 289°.41 (3 obs.)

POSITION ANGLES OF *Phobos.*

Pacific Time	Posit. Angle	Remarks
h m s	°	
12 20 50	163.14	Very close to limb; difficult.

DISTANCE OF *Deimos.*

Pacific Time	Distance	Remarks
h m s	"	
12 30 40	49.73	From E limb of *Mars*.
12 33 40	33.93	" W " "
12 41 50	50.86	" E " "
12 44 5	35.08	" W " "
12 54 30	52.11	" E " "
13 0 5	36.74	" W " "
13 3 35	44.72	All from center of *Mars* and
13 5 45	45.26	considered good.
13 8 5	45.84	
13 12 10	45.93	
13 15 20	46.16	
13 17 5	46.53	
13 21 20	46.71	

POSITION ANGLES OF *Deimos.*

Pacific Time	Posit. Angle	Remarks
h m s	°	
13 25 10	292.17	
13 27 5	292.11	
13 30 10	292.01	
13 31 40	292.30	
13 35 55	293.12	
13 38 50	292.96	

13^h 45^m. Parallel = 289°.30 (3 obs.)

POSITION ANGLES OF *Phobos.*

Pacific Time	Posit. Angle	Remarks
h m s	°	
13 57 25	288.66	
13 59 30	289.19	
14 0 35	289.41	
14 8 5	290.45	

Temperature, 62° Fah.

April 13, 1888.

Night much inferior to the last two, and considerable wind blowing. All measures were made on *Deimos*, which could not always be steadily seen. After 1 A.M. the definition became so bad that observation was discontinued. No illumination was used.

11^h 58^m. Parallel = 289°.33 (3 obs.)

POSITION ANGLES OF *Deimos.*

Pacific Time	Posit. Angle	Remarks
h m s	°	
12 18 50	159.41	
12 20 55	160.98	
12 23 40	160.58	
12 26 15	161.98	
12 31 50	162.94	
12 41 10	165.52	
12 44 25	166.31	

DISTANCE OF *Deimos.*

Pacific Time	Distance	Remarks
h m s	"	
12 53 10	27.08	
12 57 35	26.62	
13 0 15	26.73	
13 4 25	25.80	
13 7 45	25.40	

Temperature, 63° Fah.

April 15, 1888.

Night clear, but windy, and definition only occasionally good. Measures were not begun until after midnight. *Phobos*, near western elongation, was surprisingly bright, but *Deimos* was dim, and the measurements of his distance were difficult.

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DISTANCE OF *Phobos*.

Pacific Time	Distance	Remarks
h m s	″	
12 21 45	18.51	All to center of *Mars*
12 23 35	18.90	
12 30 0	18.57	
12 32 5	18.29	
12 35 0	17.78	
12 37 35	17.20	
12 40 15	16.91	
12 42 30	16.71	
12 43 45	16.23	
12 45 20	15.86	

DISTANCE OF *Deimos*.

Pacific Time	Distance	Remarks
h m s	″	
12 57 40	21.75	All to center of *Mars*
13 1 45	22.05	Faint
13 11 40	22.66	Probably bad

April 19, 1888.

Night clear, but windy. Satellites bright, but blurring badly every few seconds, so that measures were somewhat difficult. The wind blowing directly into the slit disturbed the telescope.

DISTANCE OF *Phobos*.

Pacific Time	Distance	Remarks
h m s	″	
11 3 50	12.81	All from E limb of *Mars*
11 6 30	13.04	On account of frequent blurring
11 8 15	13.06	of the image, it was found
11 9 30	12.64	better to measure from the
11 11 15	12.78	center
11 12 50	20.40	From center of *Mars*
11 20 45	20.42	All from center
11 24 10	20.33	
11 25 55	20.45	
11 29 25	20.59	
11 30 55	20.24	
11 32 30	20.19	
11 36 10	19.82	
11 29 20	20.02	
11 41 55	19.68	

POSITION ANGLES OF *Phobos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
11 51 25	135.03	
11 53 30	135.54	
11 57 0	137.61	
12 0 25	137.94	
12 3 10	139.09	
12 18 10	145.79	
12 20 30	146.93	
12 23 20	149.31	
12 25 5	151.93	
12 27 35	151.76	

POSITION ANGLES OF *Phobos*. — *Continued*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
12 29 50	153.08	
12 32 35	155.40	
12 35 15	157.88	
12 39 30	161.41	Very close to limb.

12h 9m. Parallel = 289°.34 (2 obs.)

Temperature, 62° Fah.

April 20, 1888.

Night not very clear, with haze around horizon, but calm, and definition up to midnight excellent. The wind rose from the southward at that time, and the definition grew rapidly worse.

At 11h *Phobos*, east of *Mars*, was very bright, but *Deimos*, on the north, was remarkably dim. At 12h 30m, on account of bad definition and moonlight striking the object-glass, *Deimos* could not be seen.

POSITION ANGLES OF *Phobos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
10 47 45	134.57	
10 49 30	135.45	
10 51 40	136.91	
10 53 40	137.10	
10 55 0	137.39	
10 57 15	138.13	
10 59 20	138.86	
11 1 30	139.53	
11 4 5	141.19	
11 6 50	141.91	
11 8 40	142.18	
11 11 0	143.39	
11 13 5	144.22	
11 14 40	145.36	
11 17 50	146.56	
11 19 35	148.74	
11 21 40	148.81	
11 24 10	151.16	
11 27 25	153.73	
11 29 5	155.21	

11h 40m. Parallel = 289°.31 (3 obs.)

POSITION ANGLES OF *Deimos*.

Pacific Time	Posit. Angle	Remarks
h m s	°	
11 49 15	356.41	
11 52 45	359.05	
11 55 25	359.05	Dim
12 0 25	2.31	Very dim

Temperature 60° Fah.

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April 21, 1888.

High wind and poor definition. *Deimos*, near west elongation, was surprisingly bright. *Phobos* was not seen, being too close to the planet. No measurements were made.

April 28, 1888.

Night clear, but definition only fair, and wind blowing into the slit.

Deimos at east elongation was apparently as bright as *Phobos*.

Position Angles of *Phobos*.

Pacific Time	Posit. Angle	Remarks
$10^h\ 41^m\ 50^s$	$150^\circ.88$	
10 43 40	151.17	
10 47 40	154.91	
10 49 0	156.19	
10 51 5	157.06	
10 54 35	161.54	
10 56 5	163.88	

$11^h\ 0^m$. Parallel = 289°.36 (2 obs.)

Position Angles of *Deimos*.

Pacific Time	Posit. Angle	Remarks
$11^h\ 14^m\ 40^s$	$127^\circ.06$	
11 18 5	127.58	
11 20 5	127.56	
11 22 5	127.52	
11 25 25	127.17	

Temperature, 63° Fah.

As there appears to be no systematic change in the reading of the position circle at different hour-angles, the mean of all determinations of a parallel, 289°.34, has been taken in reducing the position angles.

Assuming the elements of the apparent orbits given by Mr. Marth,* a preliminary reduction of the above observations gives the following corrections to the times of elongation of the satellites.

Corrections to Marth's Ephemeris.

Phobos $+0^h.427$
Deimos $+0\ .020$

Comparison with page 452 of the *American Ephemeris and Nautical Almanac* for 1888 gives the following approximate corrections to the times of elongation:

Corrections to the American Ephemeris.

Phobos $-0^h.33$
Deimos $+0\ .35$

Phobos could be seen with the 36-inch refractor on a good night when only one-fifth of a diameter of *Mars* distant from the edge of his disc, and could be readily seen at a distance of one-fourth of a diameter. In 1890 *Phobos* will emerge from the shadow of *Mars* at this apparent distance only nine or ten days after opposition, so that the phenomenon ought to be visible here without difficulty. Unfortunately the immersion before opposition takes place at too short a distance from the planet. It is probable that the most accurate determination of the motions of the satellites will finally be obtained in this way, and the observations would be facilitated by the prediction of such eclipses as we might reasonably expect to see under the above conditions.

1888 *July* 30.

* *Monthly Notices of the Royal Astronomical Society*, Vol. XLVIII, No. 3.

THE SATELLITE OF *NEPTUNE*,

BY A. HALL.

I wish to call the attention of astronomers to the orbits of this satellite that have been computed from the observations of different observers. Referred to the orbit of *Neptune*, the longitude of the node and the inclination of the orbit of the satellite are given by Mr. Marth as follows:

Observer.	Date	n	i
Lassell	1852	176°.20	148°.33
Lassell and Marth	1864	180.41	146.19
Newcomb	1874	182.59	144.04
Hall	1883	184.31	142.38

This is a singular result, showing such large and regular variations of the node and inclination with respect to the time. There are apparently no known forces that can produce these changes, and I am inclined to think they must be caused by systematic errors in the observations. But the matter is worthy of investigation. The apparent orbit of this satellite has been very eccentric, but it is now opening, and the large telescopes will be able to observe the satellite in all parts of its orbit with ease.

As the last orbit depends on my own work, it would be better for some other observer to make a new determination.

Neptune comes into opposition about the middle of November, and will be well situated for observation at northern observatories.

Washington, 1888 *July* 30.

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FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *c* (*BROOKS*),

MADE AT THE DUDLEY OBSERVATORY,

By LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Aug. 10 10 10 10	1	9 , 3	+5 40.66	+5 1.2	10 31 28.59	+44 50 30.5	9.540	0.873
14 8 33 31	2	6 , 2	+7 38.70	+1 43.3	11 2 3.27	+44 32 29.8	9.766	0.746
16 8 25 15	3	15 , 5	+1 0.60	+4 53.2	11 17 40.55	+44 10 45.8	9.771	0.723
19 8 32 2	4	21 , 7	—2 59.13	+0 58.6	11 41 12.76	+43 21 44.6	9.768	0.776

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	10 25 48.72	—.79	+44 45 28.0	+1.3	Radcliffe ('45) 2509
2	10 54 25.35	.78	44 30 44.2	2.3	Radcliffe ('45) 2603
3	11 16 40.68	.73	44 5 49.4	3.2	56 *Ursae Majoris*
4	11 44 12.54	—.65	+43 20 44.2	+1.8	Bessel 2.461 (Weisse 836)

NOTES.

August 10. The comet is small and condensed, and with low powers has the effective brightness of a star of ninth magnitude. There is a short tail, estimated length 10′, in position angle 270°, approximately, and of the same breadth as the head. The head is round and centrally condensed, and of an outside diameter of perhaps 45″. Even at this low altitude (7°) it is not a very difficult object with filar-micrometer.

August 14. Comet very faint and difficult to observe, on account of haze and moonlight.

August 16. Comet quite faint. Appears as a rather condensed, round nebulosity of 30″ diameter. Moonlight and light haze. The comparisons should be good, however.

August 19. Sky perfectly clear. Comet appears as of the eleventh magnitude, in bright moonlight. Bessel—Lalande: —s.81 and —2″.1 $\Delta\alpha$ and $\Delta\delta$ good, for ☄ — *, good,

THE APPEARANCE OF *MARS*, JUNE 1888,

By A. HALL.

On account of the interesting discovery of canals on the surface of *Mars* the disk of the planet was carefully observed during the month of June. These observations were begun in the twilight, and were continued for some time on eighteen nights, from June 1 to July 2, inclusive. While observing the satellites in April, attempts were made on several nights to see these canals, but without success, and I determined to make the trial in twilight, when I have been able to see more detail on the surfaces of planets. However, I was not able to see anything like the regular canals drawn by European observers, although the usual reddish and dark spots and markings were visible nearly every night. The only remarkable change which I noticed during June was the diminution in the size of the white spot at the south pole of the planet. On June 1 the spots at the poles were a good deal extended, but on July 2 the one at the south pole had become very small and round.

1888 *August* 14.

OBSERVATION OF COMET 1888 *c*,

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

By Prof. EDGAR FRISBY.

[Communicated by the Superintendent.]

1888 Washington M.T.	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s		m s	′ ″	h m s	° ′ ″	s	″
Aug. 11 9 6 8	14 , 3	—1 4.81	+7 20.3	10 38 54.36	+44 48 59.9	9.758	0.791

Mean Place for 1888.0 of Comparison-Star.

α	Red. to app. place	δ	Red. to app. place	Authority
h m s	s	° ′ ″	″	
10 39 59.95	—0.78	+44 41 35.6	+4.0	Radcliffe 2554

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NEW COMET, 1888 *c* (*BROOKS*, *August* 7).

A comet was discovered by W. R. Brooks, at Geneva, N.Y., on August 7, in the approximate position:

August 7^d 8^h 45^m Washington M.T. $\alpha = 10^h\ 5^m$ $\delta = +44°\ 30'$

Motion slow easterly. It was described as rather bright, with a short tail.

FAYE'S COMET, 1888 *d*.

A dispatch received from Kiel, August 10, announces that Faye's comet has been observed at Nice in the following position:

1888 August 9.6183 Greenwich M.T. $\alpha = 5^h\ 0^m\ 27^s.6$ $\delta = +20°\ 0'\ 42''$

Daily motion, $+2^m\ 44^s$, south 2′.

ELEMENTS AND EPHEMERIS OF COMET 1888 *c* (*BROOKS*),

By LEWIS BOSS.

From Albany observations of August 10, 14 and 19, I have computed the following elements of comet 1888 *c*. The times were first corrected for aberration, and the positions (reduced to 1888.0) for parallax, by the aid of elements not differing greatly from these.

$$T = 1888 \text{ July } 30.2500 \text{ Greenwich M.T.}$$

$$\left.\begin{aligned} \omega &= 57°\ 49'\ 22'' \\ \Omega &= 101\ \ \ 5\ \ 47 \\ i &= 74\ \ \ 3\ \ 37 \end{aligned}\right\} 1888.0$$

$$\log q = 9.95424$$

The middle place gave these differences (C—O): $\Delta\lambda \cos \beta$, —5″; $\Delta\beta$, +4″. The position of August 19 depends upon a star place from Bessel's zones; but since this comet can only be observed with great difficulty, if at all, after the September moon, it appeared advisable to publish an ephemeris promptly, rather than to wait for the chance of a possibly more accurate position. The increasingly favorable position of the comet for observation will probably compensate to a great extent for the loss of intrinsic brightness.

Dudley Observatory, 1888 *August* 20.

The equations of the heliocentric coordinates are:

$$x = r\,[9.52004]\sin(v + 273°\ 21'\ 20'')$$
$$y = r\,[9.99920]\sin(v + 173\ \ 24\ \ 58\ )$$
$$z = r\,[9.97567]\sin(v + \ 82\ \ 13\ \ 58\ )$$

Ephemeris for Greenwich Midnight.

1888	App. α h m s	App. δ ° ′	log Δ	Light
Aug. 23.5	12 11 23	+41 49.1	0.1846	0.93
25.5	12 26 11	40 50.5	0.1839	
27.5	12 40 32	39 45.0	0.1839	0.87
29.5	12 54 24	38 33.3	0.1846	
31.5	13 7 45	37 16.1	0.1859	0.81
Sept. 2.5	13 20 33	35 54.2	0.1880	
4.5	13 32 49	34 28.5	0.1906	0.73
6.5	13 44 32	32 59.9	0.1939	
8.5	13 55 43	31 29.1	0.1978	0.66
10.5	14 6 22	29 56.8	0.2022	
12.5	14 16 31	28 23.8	0.2072	0.59
14.5	14 26 12	26 50.3	0.2127	
16.5	14 35 25	25 17.8	0.2186	0.52
18.5	14 44 12	23 45.8	0.2250	
20.5	14 52 35	22 15.3	0.2317	0.45

The unit of light is the brightness on August 10.

CONTENTS.

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THE

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CATALOGUE OF VARIABLE STARS,

BY S. C. CHANDLER.

Thirteen years have passed since the appearance of SCHÖNFELD's *Second Catalogue of Variable Stars*. A work that shall represent the knowledge of to-day as that did the knowledge of its date is an urgent need of this branch of astronomy. The attainment of the same thoroughness of construction as for the catalogue of 1875 would require that it should emanate from the same hand: for any other to undertake the task might seem presumptuous, were the need not so immediate. I shall not apologize, therefore, for the attempt to meet the emergency partially, by the present catalogue, premising that it is to be regarded as a preliminary publication, the defects of which are to be remedied in a subsequent edition, when the series of observations and definitive investigations now in hand shall be completed.

This catalogue is not a mere compilation; otherwise it would scarcely be worth while to add to the number of lists which have appeared from time to time, constructed on the easy method of copying bodily the data of SCHÖNFELD's work, with additions engrafted thereupon which, sometimes at least, do not suggest a high degree of emulation of the conscientious and critical care of construction typical of the original work.

The preparation of the present work involved, as the first step, the collection of all the published observations of the known variables since their discovery, including the unpublished results of my own observations, which relate, at one time or another, nearly to the whole list of variables visible in this latitude. It is the more or less complete discussion of this material which has, in general, furnished the values of the elements of the light-variations assigned in the catalogue. Where the results of other investigators have been adopted, they have been scrupulously accredited, as hereinafter described.

In the eleventh and twelfth columns of the catalogue are given the maximum and minimum brightness, with their previously observed extremes, derived from a scrutiny of the data so collated, and expressed in the prevailing scale of magnitude, namely, that of the *Uranometria Nova*, the *Durchmusterung*, the *Uranometria Argentina*, and the *Southern Durchmusterung*. Where the data unavailable to SCHÖNFELD afforded no good reason for varying the limits given in his catalogue, the latter were retained unaltered, an asterisk being affixed thereto, to indicate this fact.

The elements in the thirteenth, fourteenth and fifteenth columns, namely, the principal epochs of minimum and maximum and the periods, together with the terms depending on the higher powers, or on periodic functions of the time, in the column of remarks, are the results of original investigation in all cases where an asterisk or dagger is not affixed to the period, in the fifteenth column. The asterisk denotes that SCHÖNFELD's elements have been adopted, either from his catalogue, or from his subsequent determinations; a course which I have followed whenever it was manifest, upon examination, that no essential improvement could be obtained from the observations now at hand, or that the time required for the calculation of new elements would too long delay the publication of the present edition of this catalogue. Similarly, a dagger is affixed wherever the elements depend on any other authority, quoted in the column of remarks.

Lest it might appear that there are exceptions to the truth of the above statement, and that there are numerous cases in which credit is not here given, it is necessary to say that the list of variables published by Professor PICKERING in 1884, and reprinted from year to year, was simply copied from my catalogue in one of its earlier stages. The manuscript for this, prepared for my private use, I lent to him with permission to employ it as he pleased, disclaiming, however, responsibility for the manner in which it appeared. This accounts for the fact that many of the elements here given for the variables discovered since 1875 are identical with values which have already appeared elsewhere, but are not here distinguished by a dagger.

The results of my investigations upon the elements here incorporated are of very different orders of approximation to what may be considered the best attainable numerical values. Sometimes they were reached simply by

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comparing the observations since 1875, or thereabouts, with SCHÖNFELD's elements, and finding the new epoch from the mean of these corrections, and the new period from the comparison of this with his epoch. In a far larger number of instances, however, the discussion was of a more elaborate character, partaking of the nature of a definitive computation in many cases. I have already printed, in various places, the details of some of these determinations, and shall do the same for others as opportunity serves. I hope to be able, within a year or so, to issue a second edition of this catalogue which shall contain final elements of all the known variables, and which shall also be more precise and complete in other respects.

An analysis of the catalogue shows that, of the two hundred and twenty-five stars comprised in it, one hundred and sixty are distinctly periodic. In twelve others the periodic character is rather uncertainly defined. Fourteen are distinctly irregular, that is, are either not periodic or follow highly complicated and totally unrecognizable laws. Twelve belong to the so-called *Novae*, or have been seen at only one appearance. In regard to the remaining twenty-seven, little or nothing is known of the character of the fluctuations, the stars having been very little observed. Of the one hundred and sixty periodical variables I have been able to assign in the catalogue both maximum and minimum epochs for sixty-three stars: maximum epochs alone, for eighty-two; minimum epochs alone, for fourteen, nine of these being of the *Algol*-type; while in one the period alone is given.

The elements of one hundred and twenty-four stars are the results of my own investigations; for twenty-two I have adopted those of SCHÖNFELD, and for fourteen those of ARGELANDER, GOULD, PARKHURST, or others, after independent examination had shown that the data at hand would not give essentially improved values.

In about one-quarter of the whole number of periodical variables for which elements are given, I have found distinct evidence of systematic departure from uniformity of period. In more than a score of these instances the deviations have a character sufficiently pronounced to enable me to develop the numerical values of the constants of periodic or secular terms, with greater or less certainty; and these functions of the epoch have been inserted in the catalogue, either in the column containing the periods or in the remarks, as the convenience of the available space served.

It is of interest to recapitulate the present state of our knowledge in respect to these curious perturbations, the development of which is so important for the study of the causes of stellar variation. I have therefore collected in the following table, by what seems to be the most perspicuous form of statement, the inequalities incorporated in the elements of the catalogue. The arrangement is in order of the length of the period in the third column, which, with its variation in the fourth column, are the values of the first and second derivatives, respectively, of the elements of the catalogue; and therefore correspond to the instant of the beginning of the epoch E, reckoned from the zero of the principal epoch of maximum or minimum of the catalogue.

No.	Star	Period	Variation of Period	$A = E\theta + G$	
				θ	G
		d d	d	°	°
4826	R Hydrae	496.91+6.043 cos A	—0.453 sin A	4.3	353.7
		—0.461 E	—0.461		
		—0.004 E^2	—0.008 E		
8600	R Cassiopeae	429.00+6.423 cos A	—1.793 sin A	16.0	346.0
7120	χ Cygni	406.04+0.011 E	+0.011		
8512	R Aquarii	387.16+6.110 cos A	—1.066 sin A	10.0	235.0
8290	R Pegasi	378.10+0.340 E	+0.340		
3477	R Leonis min.	373.50—0.066 E	—0.066		
5501	S Serpentis	365.25+4.801 cos A	—0.419 sin A	5.0	30.0
5677	R Serpentis	357.60+3.927 cos A	—0.343 sin A	5.0	15.0
2946	R Cancri	352.81+0.414 E	+0.414		
6849	R Aquilae	352.30—0.800 E	—0.800		
806	*o* Ceti	331.34+1.555 cos A	—0.037 sin A	1.36	179.8
		+1.210 cos A	—0.043 sin A	2.05	70.1
		+1.296 cos A	—0.093 sin A	4.09	31.25
7220	S Cygni	323.30—0.134 E	—0.134		
5770	R Herculis	318.40+4.189 cos A	—0.877 sin A	12.0	324.0
6044	S Herculis	309.00+7.201 cos A	—0.943 sin A	7.5	100.0
3825	R Ursae Maj.	305.40—0.150 E	—0.150		
4557	S Ursae Maj.	223.92+0.204 E	+0.204		
3994	S Leonis	184.95+0.260 E	+0.260		
6512	T Herculis	164.75+0.628 cos A	—0.079 sin A	7.2	57.6
4521	R Virginis	145.63+0.545 cos A	—0.024 sin A	2.5	135.0
		+0.353 cos A	—0.028 sin A	5.0	65.0
7560	R Vulpeculae	136.90+1.396 cos A	—0.097 sin A	4.0	90.0

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No.	Star	Period	Variation of Period	A = Eθ + G θ	G
		d h m s	s	°	°
6758	β Lyrae	12 21 46 58.3			
		+0.8434 E	+0.8434		
		—0.0002 E^2	—0.0003 E		
1090	β Persei	2 20 48 55.425			
		+3.6296 cos A	—0.0012 sin A	0.02	202.5
		+1.4137 cos A	—0.0018 sin A	0.075	203.25
		+0.6109 cos A	—0.0018 sin A	0.167	90.13
6189	U Ophiuchi	0 20 7 41.600			
		—0.0004 E	—0.0004		

Besides the stars in the foregoing table, I have detected distinct evidence of similar systematic inequalities, but without attempting to determine the mathematical expressions of them, in the following cases: *S Cassiopeae*, *R Arietis*, *R Tauri*, *V Tauri*, *R Leporis*, *R Aurigae*, *R Canis minoris*, *S Canis minoris*, *R Leonis*, *R Corvi*, *T Ursae Majoris*, *S Virginis*, *R Scorpii*, *U Herculis*, *T Delphini*, *T Pegasi;* besides the well known case of *R Scuti*. And it is appropriate to add here that there are puzzling discordances between the minima of the *Algol*-type variable *Y Cygni* observed in different years, for which I can see at present no explanation.

The fact that a large proportion of the variable stars are more or less red attracted attention early in the history of the subject; and that some sort of connection between color and variability really exists is now commonly accepted, although the nature of the relation is not at all understood. It seems proper, therefore, that a statement of the degree of redness, expressed in some convenient, although arbitrary, numerical scale, should find place in a catalogue of these objects. In the tenth column I have attempted to do this as well as the material furnished by my observations will permit. In 1883 and 1884 I made a series of about one thousand estimates, by two independent methods, upon about one hundred and twenty of the telescopic periodical variables, directed to this special end. Being a continuous series, made with the same instrument (6¼-inch Clacey equatorial), they have a homogeneity which fits them to serve as a basis of classification of the variables as to redness, until something better can be provided. The details of this investigation will soon be published. The results are given in the tenth column in the figures not in parentheses. The redness is expressed to tenths of a degree of an arbitrary decimal scale, the zero of which corresponds to white light, and the other limit, ten, to the most intense shade of red of which we have cognizance in the heavens, exemplified by such stars as *S Cephei*, *V Cygni* and *R Leporis*. As nearly as the intermediate degrees of this imaginary scale can be verbally defined, 1 corresponds to the slightest perceptible admixture of yellow with the white; 2 to a yellow; 3 to yellowish orange; 4 to a full orange or orange-red; and 5 to 10 to increasing shades of intensity up to the limit described. The results are stated to tenths of the unit, not to imply that they possess by any means that order of accuracy, but simply as the casual average of the estimates. The values for the stars not included in this series are in parentheses; and are merely rude attempts to assign their redness in the same scale, from estimates made at other times, or, where these were wanting, from descriptions by other observers. Two remarks should be added; first, that my scale was formed independently of, and without reference to SCHMIDT's, and that I am not now prepared to define the relation between the two; and secondly, that I am fully aware how vague and defective this method, of estimate by reference to an arbitrary imaginary scale, is. But it is at least a beginning, if a rude one. The whole subject is beset with great difficulties, and needs thorough study by correct methods.

The places of the stars of SCHÖNFELD's catalogue were taken directly therefrom (correcting a misprint in *η Geminorum*), and those of the additional stars from the most trustworthy available sources. The equinox of 1855 is retained, as it is still, on the whole, the most convenient. On the right hand page, however, are approximate places for 1900, which equinox will be adopted as the fundamental one in some future edition, and which has been made the basis of the method of numbering about to be described.

In the outside columns of both the right and left hand pages is the number of the star, upon a system of ordinal notation designed to remedy the inconveniences attending the usual current numbers. The variables are increasing so rapidly in number that successive editions of catalogues must in future succeed each other more frequently than in the past, to serve the convenience of astronomers. A new current number with each list necessitates a reference column, for identification, of the numbers of some preceding one; or, if the numbers of any one list are retained, the interpolated stars require a suffix-letter, resulting in a hybrid notation which is exceedingly objectionable, and which sooner or later has to be re-formed; when the whole process of degeneration, with its awkwardness and confusion, begins anew. It seems certainly better to adopt a system which attaches a permanent numeral to each star, and which permits interpolation to a practically unlimited extent. I would accordingly suggest that the numbers for variable star catalogues be

(*Continued on page 92.*)

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No.	Sch.	Star	1855.0 R.A.	1855.0 Decl.	Annual Variation		Discoverer	Date	Red-ness	Magnitude Max.	Magnitude Min.
			h m s	° ′	s	′					
100		T Ceti	0 14 26	—20 51.8	+3.04	+0.33	Chandler	1881	(4)	5.1– 5.3	6.4– 7.0
107	1	T Cassiopeae	15 25	+54 59.3	3.20	0.33	Krueger	1870	7.3	7.0– 8.0	11.0–11.2*
112	2	R Andromedae	16 25	+37 46.4	3.14	0.33	Argelander	1858	5.0	5.6– 8.6*	<12.8 *
114	3	S Ceti	16 41	—10 7.9	3.05	0.33	Borrelly	1872	2.0	7.0– 8.0*	<12.5
116	4	B Cassiopeae	16 47	+63 20.6	3.27	0.33	Tycho Brahe	1572		>1 *	? *
161	5	T Piscium	24 29	+13 48.0	3.11	0.33	Luther	1855	(0)	9.5–10.2*	10.5–11.0*
209	6	α Cassiopeae	32 18	+55 44.5	3.36	0.33	Birt	1831	(5)	2.2 *	2.8 *
224		Andromedae	34 49	+40 28.3	3.25.	0.33	Hartwig	1885	(5)	7	0?
243		U Cassiopeae	38 16	+47 27.8	3.31	0.33	Espin	1887	(6)	8½?	14?
320		U Cephei	0 49 39	+81 5.6	4.90	0.33	Ceraski	1880	(0)	7.1	9.2
432	7	S Cassiopeae	1 9 4	+71 50.8	4.30	0.32	Argelander	1861	6.7	6.7– 8.6	<13.5
434	8	S Piscium	10 0	+ 8 9.9	3.12	0.32	Hind	1851	1.0	8.2– 9.3	13.5?
466		U Piscium	15 18	+12 6.4	3.16	0.32	Peters	1880		10	<14
494		R Sculptoris	20 17	—33 17.8	2.77	0.31	Gould	1872?	(9)	5¾	7¾
513	9	R Piscium	23 10	+ 2 7.9	3.09	0.31	Hind	1850	2.0	7– 8.8	<12.5 *
715	10	S Arietis	1 56 51	+11 49.7	3.21	0.29	Peters	1865	(2)	9.1– 9.8*	14?
782	11	R Arietis	2 7 53	+24 22.8	3.39	0.28	Argelander	1857	1.8	7.6– 9.0	11.7–13.0
793		T Persei	9 0	+58 16.7	4.23	0.28	Safarik	1882	(4)	8.2	9.3
806	12	o Ceti	12 1	— 3 38.3	3.02	0.28	Fabricius	1596	5.9	1.7– 5.0*	8– 9.5
814	13	S Persei	12 29	+57 55.2	4.24	0.28	Krueger	1873	5.0	8.5	12.5
845	14	R Ceti	18 38	— 0 50.1	3.06	0.28	Argelander	1866	2.4	7.5– 8.8	13.5
893		U Ceti	26 45	—13 47.2	2.88	0.27	Sawyer	1885	(3)	6.8– 7.3	10.5<
976	15	T Arietis	40 15	+16 54.1	3.33	0.26	Auwers	1870	3.2	7.9– 8.6	9.3– 9.7
1072	16	ρ Persei	55 54	+38 16.5	3.81	0.24	Schmidt	1854	(2)	3.4 *	4.2 *
1090	17	β Persei	2 58 45	+40 23.6	3.87	0 24	{Montanari / Goodricke}	{1669 / 1783}	(0)	2.3	3.5
1222	18	R Persei	3 20 50	+35 10.1	3.79	0.21	Schönfeld	1861	2.3	7.7– 9.2	13.5
1411	19	λ Tauri	3 52 39	+12 4.6	3.31	0.18	Baxendell	1848	(0)	3.4 *	4.2 *
1537	20	T Tauri	4 13 33	+19 11.3	3.49	0.15	Hind	1861	(0)	9.2–11.5*	12.8–<13.5
1574		W Tauri	19 43	+15 46.5	3.41	0.14	Espin	1886	(5)	9?	<12½
1577	21	R Tauri	20 21	+ 9 50.1	3.28	0.14	Hind	1849	4.5	7.4– 9.0*	13.5
1582	22	S Tauri	21 16	+ 9 37.3	3.28	0.14	Oudemans	1855	2.5	9.5–10.0	<13.5
1654		R Doradus	35 5	—62 21.8	0.69	0.12	Gould	1874?	(7)	5½	6¾
1717	23	V Tauri	43 39	+17 17.4	3.46	0.11	Auwers	1871	3.3	8.3– 9.0*	<13.5
1761	24	R Orionis	51 8	+ 7 54 3	3.25	0.10	Hind	1848	4.4	8.7– 9.1	<13 *
1768	25	ε Aurigae	51 34	+43 36.2	4.29	0.10	Fritsch	1821	(1)	3.0 *	4.5 *
1771	26	R Leporis	4 53 0	—15 1.7	2.73	0.10	Schmidt	1855	9.4	6– 7 *	8.5? *
1855	27	R Aurigae	5 5 36	+53 25.0	4.82	0.08	At Bonn	1862	6.5	6.5– 7.8	12.5–12.7*
1923		S Aurigae	17 33	+34 2.1	3.96	0.06	Dunér	1881	6.7	9.4–11.0	<14.5
1944	28	S Orionis	21 51	— 4 48.7	2.96	0.06	Webb	1870	6.4	8.3– 9.5	13.0
1961	29	δ Orionis	24 36	— 0 24.6	3.06	0.05	J. Herschel	1834	(0)	2.2? *	2.7 *
1986		T Orionis	28 43	— 5 34.5	2.94	0.05	Bond	1863	(0)	9.7	13
2100		U Orionis	47 13	+20 8.7	3.56	0.02	Gore	1885	(7)	6.4– 7.5	<12
2098	30	α Orionis	5 47 19	+ 7 22.9	3.25	+0.02	J. Herschel	1840	(6)	1 *	1.4 *
2213	31	η Geminorum	6 6 8	+22 32.6	3.62	—0.01	Schmidt	1865	(3)	3.2 *	3.7– 4.2*
2266		V Monocerotis	15 25	— 2 7.6	3.02	0.02	Schönfeld	1883	3.4	6.9	10.7<
2279	32	T Monocerotis	17 24	+ 7 9.7	3.24	0.03	Gould	1871	(2)	5.8– 6.4	7.4– 8.2
2362	33	R Monocerotis	31 15	+ 8 51.7	3.28	0.05	Schmidt	1861	(0)	9.5 *	13
2375	34	S Monocerotis	33 0	+10 1.5	3.31	0.05	Winnecke	1867	(2)	4.9 *	5.4 *
2478	35	R Lyncis	49 20	+55 31.6	4.97	0.07	Krueger	1874	4.8	7.8– 8.0	<13
2509	36	ζ Geminorum	55 30	+20 46.7	3.56	0.08	Schmidt	1847	(2)	3.7 *	4.5 *
2528	37	R Geminorum	6 58 37	+22 55.4	3.62	0.08	Hind	1848	5.7	6.6– 7.8	<13.5
2539	38	R Canis min.	7 0 44	+10 14.9	3.30	0.09	At Bonn	1855	5.5	7.2– 7.9*	9.5–10.0*
2583		L_2 Puppis	9 7	—44 24.2	1.82	0.10	Gould	1872	(8)	3.5	6.3
2610		R Canis Maj.	12 55	—16 7.6	2.70	0.10	Sawyer	1887	(0)	5.9	6.7
2625		V Geminorum	15 2	+13 21.9	3.37	0.11	Baxendell	1880	2.8	8.2– 9.1	12.0–14.0
2676	39	U Monocerotis	23 53	— 9 28.6	2.86	0.12	Gould	1873	(3)	5.9– 7.3	6.6– 8.0
2684		S Canis min.	7 24 51	+ 8 37.4	+3.26	—0.12	Hind	1856	4.1	7.2– 8.0*	<11 *

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Greenwich Mean Time Min.	Greenwich Mean Time Max.	Period, etc.	Remarks	1900.0 R.A.	1900.0 Decl.	No.
d h m	d h m	d h m s		h m	° ′	
. . . .	. . . .	65 ?	Irregular; possibly, type of R Scuti	0 16.7	—20 37	100
83 Dec. 8	84 Aug. 10	+441 E		17.8	+55 14	107
. . . .	82 Oct. 22.9	+411.2 E		18.8	+38 1	112
. . . .	88 Nov. 13	+822.5 E		19.0	— 9 53	114
. . . .	. . . .	. . . .	Nova	19.2	+63 35	116
. . . .	. . . .	. . . .	Irregular	26.8	+14 3	161
. . . .	. . . .	. . . .	Irregular. Argel. found per. 79d	34.8	+55 59	209
. . . .	. . . .	. . . .	Nova in Andromeda Nebula	37.2	+40 43	224
. . . .	. . . .	. . . .		40.5	+47 43	243
88 Jan. 2 23 20.0	. . . .	+ 2 11 49 45.0 E	Algol-type	0 53.4	+81 20	320
. . . .	88 Apr. 27.5	+607.5 E	I think period is shortening	1 12.3	+72 5	432
. . . .	88 Mar. 31.7	+406.0 E		12.3	+ 8 24	434
. . . .	85 Sept.	+352 E †	Elements uncertain; Parkhurst	17.7	+12 21	466
72 Aug. 21 ?	72 Dec. 7 ?	+207 E	Elements inferred from Cordoba obser. Sawyer has confirmed variability	22.4	—33 4	494
. . . .	81 Dec. 24.0	+344.0 E		25.5	+ 2 22	513
. . . .	72 Mar. 14.0	+290.0 E		1 59.2	+12 3	715
81 Sept. 27.6	82 Jan. 6.5	+186.7 E	I suspect a shortening of period	2 10.4	+24 35	782
. . . .	. . . .	. . . .	Light-curve irregular	12.2	+58 29	793
66 Aug. 8	66 Nov. 25.47	+331.3363 E+ †	{+18d .16 sin(45/11° E+ 31° 15′) +33 .90 sin(45/22° E+ 70 5) +35 .31 sin(15/11° E+ 179 48) Argel. elements, omitting 10-year term	14.3	— 3 26	806
. . . .	73 Nov. 30	+346 E		15.7	+58 8	814
. . . .	70 Oct. 31.4	+167.1 E *		20.9	— 0 38	845
. . . .	84 Dec. 11	+233 E		28.9	—13 35	893
72 Nov. 8	73 Mar. 11	+324 E *		42.7	+17 6	976
. . . .	. . . .	33	Schmidt's period. Schoenfeld thinks the var. irregular	2 58.7	+38 27	1072
88 Jan. 3 7 21 29.23	. . . .	+ 2 20 48 55.425 E′+	{+173m .3 sin(1/50 E′+202° 30′) + 18 .0 sin(5/40 E′+203 15) + 3 .5 sin(1/6 E′+ 90 20); where E′ = E —11210	3 1.6	+40 34	1090
. . . .	82 June 20.0	+210.4 E		23.7	+35 20	1222
87 Dec. 6 11 57.0	. . . .	+ 3 22 52 12.0 E	Algol-type: period subject to marked inequalities	3 55.1	+12 12	1411
. . . .	. . . .	. . . .	Irregular	4 16.2	+19 18	1537
. . . .	. . . .	. . . .		22.3	+15 53	1574
. . . .	81 Nov. 26.9	+325.0 E		22.8	+ 9 56	1577
. . . .	83 Oct. 25	+376 E	Elements uncertain	23.7	+ 9 44	1582
. . . .	. . . .	. . . .		35.6	—62 16	1654
. . . .	83 Nov. 7	+169.2 E	I suspect variation from uniform period	46.2	+17 22	1717
. . . .	69 Oct. 18.6	+378.8 E *		53.6	+ 7 59	1761
. . . .	. . . .	. . . .	Irregular	54.8	+43 41	1768
79 Jan. 24	79 Sept. 13.0	+436.1 E	Evidence of inequality in period	4 55.0	—14 57	1771
77 May 25	78 Jan. 6.0	+460.6 E	Period probably irregular	5 9.2	+53 29	1855
. . . .	. . . .	. . . .	I think period is certainly over 400 days, but very irregular; possibly with secondary phases	20.5	+34 5	1923
69 July 1	70 Jan. 17	+416 E	Possibly a secondary max. midway	24.1	— 4 46	1944
. . . .	. . . .	. . . .	Auwers found a 16d period; Schoenfeld found a slight variation, but no period. My obsns. and Sawyer's show no fluctuation of light	26.9	— 0 22	1961
. . . .	. . . .	. . . .	In Great Nebula; Schmidt's obsns. and mine confirm variability	30.9	— 5 32	1986
. . . .	85 Dec. 15	+359.5 E †	Duner's elements	49.9	+20 10	2100
. . . .	. . . .	. . . .	Argelander found period 196 days. Schoenfeld thinks periodicity questionable	5 49.7	+ 7 23	2098
70 April 7	. . . .	+229.1 E *		6 8.8	+22 32	2213
. . . .	84 Jan. 1	+334 E		17.7	— 2 9	2266
85 Mar. 24.88	85 Apr. 1.81	+ 27.0037 E	Limits of mags. from Sawyer's obsns.	19.8	+ 7 8	2279
. . . .	. . . .	. . . .	Irregular; in southerly end of the nebular h (399)	33.7	+ 8 49	2362
70 Feb. 2 10.4 ?	70 Jan. 31 19.9 ?	+ 3 10 38 E? †	Winnecke's elements; Schoenfeld's obsns. partly confirm such a period, partly contradict it	35.8	+ 9 59	2375
83 Aug. 20	84 Jan. 26	+380.0 E	Elements uncertain	53.1	+55 29	2478
87 Dec. 29 14 5.7	88 Jan. 3 14 27.7	+ 10 3 41.5 E	W. M. Reed's obsns. indicate a correction to Schoenfeld's period of —1m 48s, Yendell's one of about —30s. I have adopted —1m 22s	6 58.2	+20 43	2509
78 Jan. 0	78 Apr. 18.0	+370.5 E		7 1.3	+22 52	2528
76 Apr. 28	76 Aug. 20	+337.5 E	There is evidence of inequality of period	3.2	+10 11	2539
78 Jan. 4	78 Mar. 16.0	+136.05 E †	Williams's elements of max.; min. inferred from Gould's remarks in U.A.	10.5	—44 29	2583
87 Mar. 26 14 58.5	. . . .	+ 1 3 15 55 E	Algol-type	14.9	—16 12	2610
79 Sept. 24	80 Feb. 7	+276.0 E	Limits of mag. from Sawyer's obsns., which show light-curve resembling R Scuti; Yendell's obsns. confirm	17.6	+13 17	2625
73 Apr. 1 0	73 Apr. 19.0	+ 45.20 E		26.0	— 9 34	2676
. . . .	79 Aug. 20	+331.0 E	Schoenfeld thought period was shortening, in 1875; but my results show rather a cyclical irregularity	7 27.3	+ 8 32	2684

No.	Sch.	Star	1855.0 R.A.	1855.0 Decl.	Annual Variation		Discoverer	Date	Redness	Magnitude Max.	Magnitude Min.
			h m s	° ′	s	′					
2691	40	T Canis min.	7 25 56	+12 3.0	+3.34	—0.12	Schönfeld	1865	(2)	9.0– 9.7	<13.5
2735		U Canis min.	33 28	+ 8 42.2	3.26	0.13	Baxendell	1879	5.1	8.5– 9.0	12.3–13.5
2742	41	S Geminorum	34 20	+23 47.2	3.61	0.13	Hind	1848	(3)	8.2– 8.7*	<13.5
2780	42	T Geminorum	40 36	+24 5.5	3.61	0.14	Hind	1848	3.0	8.1– 8.7*	<13.5
2783		S Puppis	42 31	—47 45.4	1.74	0.14	Gould	1872?		7¼	9
2815	43	U Geminorum	46 30	+22 22.7	3.56	0.15	Hind	1855	0.0	8.9– 9.7*	13.1 *
2857		U Puppis	7 54 2	—12 26.6	2.81	0.16	Pickering	1881	3.2	8.5– 9.0	< 14
2946	44	R Cancri	8 8 34	+12 10.1	3.32	0.18	Schwerd	1829	5.3	6.0– 8.3	<11.7 *
2976	45	V Cancri	13 27	+17 44.5	3.43	0.18	Auwers	1870	4.3	6.8– 7.7	<12 *
3060	46	U Cancri	27 28	+19 23.5	3.45	0.20	Chacornac	1853	2.3	8.4–10.6	<13 *
3109	47	S Cancri	35 39	+19 33.2	3.44	0.21	Hind	1848	(1)	8.2 *	9.8 *
3170	48	S Hydrae	46 0	+ 3 36.8	3.13	0.22	Hind	1848	2.1	7.5– 8.7	<12.2 *
3186	49	T Cancri	48 23	+20 24.1	3.44	0.22	Hind	1850	7.4	8.0– 8.5	9.3–10.5*
3184	50	T Hydrae	8 48 37	— 8 35.4	2.92	0.22	Hind	1851	1.8	7.0– 8.1*	<13.0
3418		R Carinae	9 28 36	—62 8.9	1.52	0.26	Gould	1871	(5)	4.3– 5.7	9.3–10.0
3477	51	R Leonis min.	36 52	+35 10.6	3.62	0.27	Schönfeld	1863	6.0	6.1– 7.8	<12.5
3493	52	R Leonis	39 45	+12 5.9	3.23	0.27	Koch	1782	6.9	5.2– 6.7	9.4–10.0*
3495		*l* Carinae	41 16	—61 50.4	1.65	0.27	Gould	1871		3.7	5.2
3567		V Leonis	9 51 57	+21 57.3	3.36	0.28	Becker	1882	1.7	8.6	<13.5
3633		R Antliae	10 3 30	—37 1.2	2.58	0.29	Gould	1872		6.5	<8
3637		S Carinae	4 45	—60 50.4	1.92	0.29	Gould	1871	(5)	6¼	9
3712		U Leonis	16 17	+14 44.1	3.23	0.30	Peters	1876		9.5	<13.5
3796		U Hydrae	30 24	—12 38.1	2.96	0.31	Gould	1871	(7)	4.5	6.1– 6.3
3825	53	R Ursae Maj.	34 19	+69 32.1	4.38	0.31	Pogson	1853	1.6	6.0– 8.2	13.2
3847	54	η Argus	39 27	—58 55.4	2.31	0.31	Burchell	1827	(5)	>1 *	7.4
3881		V Hydrae	44 34	—20 28.8	2.91	0.32	{Gould, Chandler}	{1874?, 1888}	(9)	6.7	9.1<
3890		W Leonis	45 58	+14 29.2	3.18	0.32	Peters	1880		9?	< 14
3934	55	R Crateris	10 53 26	—17 32.8	2.95	0.32	Winnecke	1861	8.1	>8 *	<9 *
3994	56	S Leonis	11 3 21	+ 6 14.9	3.11	0.32	Chacornac	1856	0.0	9.0–10.0	<13 *
4160	57	T Leonis	31 0	+ 4 10.5	3.08	0.33	Peters	1862		10? *	<13.5
4300	58	X Virginis	54 25	+ 9 52.7	3.08	0.33	Peters	1871		7.8? *	12
4315	59	R Comae	11 56 49	+19 35.4	3.08	0.33	Schönfeld	1856	4.0	7.4– 8.0*	<13.5
4377	60	T Virginis	12 7 10	— 5 13.8	3.08	0.33	Boguslawski	1849	4.1	8.0– 8.8*	10–<13.5
4407	61	R Corvi	12 8	—18 26.9	3.09	0.33	Karlinski	1867	3.7	6.8– 7.7	<11.5 *
4492		Y Virginis	26 25	— 3 37.3	3.08	0.33	Henry	1874	3.6	8– 9.4	13–14
4511	62	T Ursae Maj.	29 47	+60 17.2	2.77	0.33	At Bonn	1860	2.0	6.7– 8.5	12.2–12.6
4521	63	R Virginis	31 9	+ 7 47.2	3.05	0.33	Harding	1809	1.3	6.5– 8.0	9.7–11.0
4536		R Muscae	33 17	—68 36.7	3.56	0.33	Gould	1871		6.6	7.4
4557	64	S Ursae Maj.	37 35	+61 53.3	2.66	0.33	Pogson	1853	3.2	7.0– 8.2	10.2–11.5
4596	65	U Virginis	12 43 45	+ 6 20.6	3.04	0.33	Harding	1831	1.1	7.7– 8.1*	12.2–12.8*
4805	66	W Virginis	13 18 33	— 2 37.4	3.09	0.31	Schönfeld	1856	0.4	8.7– 9.2*	9.8–10.4*
4816	67	V Virginis	20 19	— 2 25.2	3.09	0.31	Goldschmidt	1857	2.7	8.0– 9.0*	<13 *
4826	68	R Hydrae	21 48	—22 31.8	3.27	0.31	{Montanari, Maraldi}	{1672, 1704}	5.9	3.5– 5.5	9.7
4847	69	S Virginis	25 26	— 6 26.8	3.13	0.31	Hind	1852	2.6	5.7– 7.8*	12.5 *
4948		R Canum Venat.	42 43	+40 15.9	2.58	0.30	Espin	1888		7½ *	<11
5037		RR Virginis	13 57 12	— 8 30.0	3.17	0.29	Peters	1880		>11	<14
5070		Z Virginis	14 2 33	—12 36.5	3.22	0.29	Palisa	1880		9.5– 11	<14
5095		R Centauri	6 10	—59 14.1	4.24	0.28	Gould	1871	(6)	6.0– 6.3	8.7– 9.8
5097	70	T Bootis	7 18	+19 44.7	2.81	0.28	Baxendell	1860		9.7? *	<13 *
5156		X Bootis	17 19	+16 58.8	2.84	0.28	Baxendell	1859	(4)	9.0– 9.4	10.2
5157	71	S Bootis	18 1	+54 28.3	2.01	0.28	At Bonn	1860	2.8	7.7– 8.5	12.5–13.2
5194		V Bootis	23 54	+39 30.4	+2.42	0.27	Dunér	1884	3.6	7.1– 7.3	9.4
5190	72	R Camelopardi	28 54	+84 29.2	—5.31	0.27	Hencke	1858	2.1	7.8– 8.6	12–13.5
5237	73	R Bootis	30 48	+27 22.1	+2.65	0.26	At Bonn	1858	2.7	5.9– 7.8	11.3–12.2*
5249		V Librae	14 32 18	—17 1.8	+3.32	—0.26	Schönfeld	1882		9.3	12.2

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Greenwich Mean Time Min.	Max.	Period, etc.	Remarks	1900.0 R.A.	Decl.	No.
d h m	d h m	d h m s		h m	° ′	
. . . .	72 Feb. 3.6	+322.1 E *		7 28.4	+11 58	2691
79 Aug. 27	80 Mar. 15	+398.6 E		35.9	+ 8 36	2735
. . . .	65 Nov. 3.2	+294.2 E *		37.0	+23 41	2742
. . . .	63 Feb. 18.3	+288.1 E *		43.3	+23 59	2780
. . . .	. . . .	. . . .		43.8	—47 52	2783
. . . .	79 Oct. 24	+ 86.3 E	Law of period very complicated. The elements given represent obsns. since 1879, but with considerable deviations	49.2	+22 16	2815
. . . .	81 Mar. 8	+310 E		7 56.1	—12 34	2857
. . . .	52 Apr. 21.1	+352.81 E+0.207 E^2	A lengthening of the period seems beyond doubt	8 11.0	+12 2	2946
. . . .	84 Jan. 8.5	+271.5 E		16.0	+17 36	2976
. . . .	84 Mar. 18.6	+305.2 E		30.0	+19 14	3060
67 Aug. 31 14 2.89	. . . .	+ 9 11 37 45 E *	Algol-type	38.2	+19 24	3109
. . . .	78 Mar. 18.3	+256.5 E		48.3	+ 3 27	3170
72 Aug. 2	. . . .	+482 E	Elements uncertain	51.0	+20 14	3186
. . . .	66 Jan. 26.5	+289.4 E *		8 50.8	— 8 45	3184
. . . .	71 July 26.1	+312.14 E		9 29.7	—62 21	3418
. . . .	65 Feb. 20.0	+373.5 E—0.033 E^2	The shortening of the period seems clearly proved	39.6	+34 58	3477
80 Apr. 2.4	80 Aug. 28.4	+312.87 E	I find good evidence of cyclical variation of period. with a long term.	42.2	+11 54	3493
71 July 12	71 Aug. 1	+ 31.0 E		42.5	—62 3	3495
. . . .	82 April	+280 E	Elements mere guess-work	9 54.5	+21 45	3567
. . . .	. . . .	. . . .		10 5.5	—37 14	3633
. . . .	. . . .	. . . .	Period several months	6.2	—61 4	3637
. . . .	. . . .	. . . .		18.7	+14 31	3712
86 Mar. 29	85 Dec. 11.73	+194.65 E †	Elements are Espin's, very uncertain. Sawyer's obsns. confirm variability but give no period	32.6	—12 52	3796
52 Oct. 23	53 Mar. 12.5	+305.4 E—0.075 E^2	Elements provisional; whether the marked deviations from uniform period are secular or not is uncertain	37.6	+69 18	3825
. . . .	. . . .	. . . .	Irregular	41.2	—59 10	3847
. . . .	73 March	+575 E	Elements very uncertain	46.8	—20 43	3881
. . . .	87 March?	+395 E ? †	Elements inferred by Parkhurst from his observations	48.3	+14 15	3890
. . . .	. . . .	. . . .	Schoenfeld finds, very uncertainly, period of 160d	10 55.6	—17 47	3934
. . . .	61 Jan. 3.0	+184.95 E+0.13 E^2		11 5.7	+ 6 0	3994
. . . .	. . . .	. . . .		33.3	+ 3 56	4160
. . . .	. . . .	. . . .		56.7	+ 9 38	4300
. . . .	83 Sept. 15	+362 E	Elements very uncertain	11 59.1	+19 21	4315
. . . .	75 Mar. 14	+337 E	" " "	12 9.5	— 5 28	4377
. . . .	77 Dec. 31	+317.2 E	Periodical inequality evident	14.5	—18 42	4407
84 February	84 May	+210 E	Elements very uncertain	28.7	— 3 52	4492
82 Apr. 30	82 Aug. 21.0	+257.2 E	Evidence of periodical irregularity	31.9	+60 3	4511
09 Mar. 11.17	09 May 29.17	+145.63 E+	$+12^d.5\sin(2^\circ.5\,E+135^\circ)$ $+\;4\;.5\sin(5\;\;0\,E+\;65\;)$ Elements provisional	33 4	+ 7 33	4521
. . . .	. . . .	0 21 20 †	Period is Gould's; min. precedes max. 9 hours	36.0	—68 51	4536
60 Feb. 4.0	60 May 21.4	+223.92 E+0.102 E^2	Signs of periodical irregularity	39.6	+61 39	4557
82 Feb. 13.0	82 May 12.0	+207.2 E		12 46.0	+ 6 6	4596
69 Apr. 17.466	69 Apr. 25.666	+ 17.27263 E *		13 20.9	— 2 52	4805
. . . .	67 Sept. 4	+251 E *		22.6	— 2 39	4816
. . . .	1764 Dec. 22.5	+496.91 E—0.2307 E^2	$-0^d.001276\,E^3$ $+80^d.5\sin(4^\circ.3\,E+353^\circ.7)$ Gould has an entirely different law	24.2	—22 46	4826
63 Feb. 9	63 May 17.0	+376.0 E	Schoenfeld favors assumption of secular shortening of period; my results show rather periodical irregularity	27.8	— 6 41	4847
. . . .	. . . .	. . . .		44.6	+40 2	4948
. . . .	86 June	+383 E †	Elements inferred by Parkhurst from his observations	13 59.6	— 8 43	5037
. . . .	80 May 25.4	+302.6 E	Elements represent Markree observation in 1855	14 5.0	—12 50	5070
. . . .	. . . .	. . . .	Period probably long and irregular	9.4	—59 27	5095
. . . .	. . . .	. . . .	Only one appearance known	9.4	+19 32	5097
82 Aug. 15	82 Nov. 7	+123 E		19.4	+16 46	5156
80 Jan. 14	80 June 9.0	+272.3 E		19.5	+54 16	5157
85 Jan. 29	84 Sept. 3	+266.5 E †	Duner's elements	25.7	+39 18	5194
. . . .	82 Dec. 10	+269.5 E		25.1	+84 17	5190
80 Mar. 13	80 June 23.0	+223.9 E		32.8	+27 10	5237
. . . .	. . . .	. . . .		14 34.8	—17 14	5249

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No.	Sch.	Star	1855.0 R.A.	1855.0 Decl.	Annual Variation		Discoverer	Date	Red-ness	Magnitude Max.	Magnitude Min.
			h m s	° ′	s	′					
5274		W Bootis	14 37 3	+27 8.9	+2.64	—0.26	Schmidt	1867		5.2	6.1
5338		U Bootis	47 37	+18 17.1	2.78	0.25	Baxendell	1880	2.7	9.1– 9.3	12–13.6
5374	74	δ Librae	14 53 14	— 7 56.4	3.20	0.24	Schmidt	1859	(1)	5.0	6.2
5430		T Librae	15 2 28	—19 27.8	3.41	0.23	Palisa	1878		10.2	<14
5438		Y Librae	4 2	— 5 27.6	3.16	0.23	Bauschinger	1887		8½	?
5465		R Triang. austr.	6 52	—65 57.5	5.25	0.23	Gould	1871		6.6	8.0
5484	75	U Coronae	12 17	+32 10.8	2.45	0.22	Winnecke	1869	0.0	7.5	8.9
5494	76	S Librae	13 4	—19 51.7	3.43	0.22	Borrelly	1872	3.0	8.0– 8.3	<13
5501	77	S Serpentis	14 52	+14 50.3	2.81	0.22	Harding	1828	4.1	7.6– 8.7	12.5? *
5504	78	S Coronae	15 29	+31 53.5	2.44	0.22	Hencke	1860	4.9	6.1– 7.8*	11.9–12.5*
5583		X Librae	27 50	—20 40.8	3.47	0.21	Peters	1878		11?	<14
5593		W Librae	29 40	—15 41.5	3.37	0.20	Peters	1878		11?	<14
5617		U Librae	33 37	—20 42.6	3.48	0.20	Peters	1878	3.4	9	<14
5667	79	R Coronae	42 36	+28 36.3	2.47	0.19	Pigott	1795	0.5	5.8 *	13.0 *
5677	80	R Serpentis	44 1	+15 34.6	2.76	0.19	Harding	1826	3.7	5.6– 7.6*	13
5682		R Lupi	44 5	—35 51.6	3.87	0.19	Gould	1884		9	<11
5675		V Coronae	44 21	+40 0.7	2.14	0.19	Dunér	1878	5.9	7.2– 7.7	10.3–12.0
5688	81	R Librae	45 24	—15 48.1	3.39	0.18	Pogson	1858	(2)	9.2–10.0*	<13 *
5732	82	T Coronae	53 26	+26 20.1	2.51	0.18	Birmingham	1866	(1)	2.0 *	9.5 *
5770	83	R Herculis	15 59 43	+18 45.9	2.68	0.17	At Bonn	1855	2.0	8.0– 9.2	<13 *
5776		X Scorpii	16 0 2	—21 8.3	3.52	0.17	Peters	1876		>11	<13
5795		W Scorpii	3 18	—19 45.3	3.49	0.16	J. Palisa	1877		10–11.2	14.5
5826	84	T Scorpii	8 25	—22 36.7	3.56	0.16	Auwers	1860		7.0 *	<12
5830	85	R Scorpii	9 1	—22 35.0	3.56	0.16	Chacornac	1853	0.9	9.4–10.5	<13
5831	86	S Scorpii	9 2	—22 32.0	3.56	0.16	Chacornac	1854	(0)	9.1–10.5*	<13
5856		W Ophiuchi	13 36	— 7 21.3	3.23	0.15	Schönfeld	1881	3.0	8.9– 9.5	<13.5
5860	87	U Scorpii	14 7	—17 32.3	3.44	0.15	Pogson	1863		9? *	<12 *
5887		V Ophiuchi	18 40	—12 5.5	3.33	0.14	Dunér	1881	6.6	7.0	9.6–10.5
5889	88	U Herculis	19 23	+19 13.6	2.65	0.14	Hencke	1860	6.5	6.6– 7.8	11.4–12.7
5912	89	g Herculis	23 53	+42 12.2	1.97	0.13	Baxendell	1857	(3)	4.7– 5.5	5.4– 6.0
5928	90	T Ophiuchi	25 27	—15 49.2	3.42	0.13	Pogson	1860		10 *	<12.5 *
5931	91	S Ophiuchi	25 55	—16 51.1	3.44	0.13	Pogson	1854	(1)	8.3– 9.0*	<13
5950		W Herculis	30 5	+37 38.1	+2.12	0.13	Dunér	1880	3.2	8.0– 8.4	11.5–14
5948		R Ursae min.	31 57	+72 34.4	—0.88	0.13	Pickering	1881	3.2	8.6– 9.0	10.5
5955		R Draconis	32 17	+67 3.5	+0.14	0.12	Geelmuyden	1876	2.0	6.5– 8.7	13
6044	92	S Herculis	45 18	+15 11.4	2.73	0.11	At Bonn	1856	5.6	5.9– 7.5	11.5–13
6083	93	Ophiuchi	51 23	—12 40.0	3.36	0.10	Hind	1848	(5)	5.5 *	12.5 *
6088		V Herculis	52 58	+35 17.4	2.17	0.10	Baxendell	1880	1.0	9.5	11.7
6132	94	R Ophiuchi	16 59 27	—15 53.7	3.44	0.09	Pogson	1853	4.5	7.0– 8.1	<12 *
6181	95	α Herculis	17 8 2	+14 33.5	2.73	0.07	W. Herschel	1795	(5)	3.1 *	3.9 *
6189		U Ophiuchi	9 11	+ 1 22.6	3.04	0.07	Gould / Sawyer	1871 / 1881	(0)	6.0	6.7
6202	96	u Herculis	11 58	+33 15.5	2.21	0.07	Schmidt	1869?	(4)	4.6 *	5.4 *
6268	97	Serpentarii	21 57	—21 21.2	3.59	0.06	Fabricius	1604		>1 *	? *
6368	98	X Sagittarii	38 26	—27 46.2	3.77	0.03	Schmidt	1866	(1)	4 *	6 *
6472	99	W Sagittarii	17 55 45	—29 34.9	3.83	—0.01	Schmidt	1866	(1)	5 *	6.5 *
6512	100	T Herculis	18 3 37	+30 59.9	2.27	+0.01	At Bonn	1857	1.4	6.9– 8.5	9.8–12.7
6573		Y Sagittarii	12 51	—18 55.2	3.53	0.02	Sawyer	1886	(0)	5.8	6.6
6624	101	T Serpentis	21 44	+ 6 12.5	2.93	0.03	Baxendell	1860	2.0	9.1–10.5	<13.5
6633	102	V Sagittarii	22 54	—18 21.5	3.51	0.03	Quirling	1865	0.6	7.6	8.8
6636	103	U Sagittarii	23 21	—19 13.3	3.53	0.03	Schmidt	1866	3.7	7.0 *	8.3 *
6682		X Ophiuchi	31 26	+ 8 42.3	2.87	0.05	Espin	1886	(5)	6.8	9?
6726	104	T Aquilae	38 47	+ 8 35.7	2.88	0.06	Winnecke	1860	3.3	8.8 *	10.0
6733	105	R Scuti	39 45	— 5 51.4	3.21	0.06	Pigott	1795	(4)	4.7– 5.7*	6.0– 9.0
6760		κ Pavonis	41 58	—67 24.4	6.23	0.06	Thome	1872		4.0	5.5
6758	106	β Lyrae	44 44	+33 11.8	2.21	0.06	Goodricke	1784	(1)	3.4 *	4.5 *
6794	107	R Lyrae	18 50 55	+43 45.5	+1.83	+0.08	Baxendell	1856	(4)	4.0	4.7

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Greenwich Mean Time Min.	Max.	Period, etc.	Remarks	1900.0 R.A.	Decl.	No.
d h m	d h m	d h m s		h m	° ′	
. . . .	. . . .	. . . .	Period long and irregular. Variability confirmed by Schwab	14 39.0	+26 57	5274
. . . .	80 Mar. 25.5	+173.8 E		49.7	+18 6	5338
67 Oct. 25 9 17.5	. . . .	+ 2 7 51 22.8 E	Algol-type	14 55.6	− 8 7	5374
. . . .	78 May 30	+723 E		15 5.0	−19 38	5430
. . . .	. . . .	. . . .		6.4	− 5 38	5438
71 July 12 16	71 July 14 15	+ 3 9 35 E †	Period is Gould's. Epochs of max. and min. inferred from Cordoba observations	10.8	−66 8	5465
88 Jan. 0 13 8	. . . .	+ 3 10 51 8.6 E	Algol-type	14.1	+32 1	5484
79 Dec. 23	80 Apr. 1	+192.3 E		15.6	−20 2	5494
. . . .	28 Apr. 2.5	+365.25 E	+55d sin (5° E+30°)	17.0	+14 40	5501
82 Jan. 16	82 May 16.8	+360.57 E		17.3	+31 44	5504
. . . .			Parkhurst confirms variability	30.4	−20 50	5583
. . . .	. . . .	. . . .	" " "	32.2	−15 51	5593
. . . .	. . . .	. . . .	My observations confirm variability, but give no times of maxima	36.2	−20 52	5617
. . . .	. . . .	. . . .	Irregular	44.4	+28 28	5667
. . . .	27 May 2.0	+357.6 E	+45d sin (5° E+15°)	46.1	+15 26	5677
. . . .	. . . .	. . . .		47.0	−36 0	5682
. . . .	78 Oct. 13.3	+359.5 E		46.0	+39 52	5675
. . . .	58 Apr. 6	+730 E	Elements very uncertain	47.9	−15 56	5688
. . . .	. . . .	. . . .	Nova	15 55.3	+26 12	5732
. . . .	65 July 18.0	+318.4 E	+20d sin (12° E+324°)	16 1.7	+18 38	5770
. . . .	. . . .	. . . .	Parkhurst thinks the changes are irregular.	2.7	−21 16	5776
. . . .	76 May 18	+224.3 E		5.9	−19 52	5795
. . . .	. . . .	. . . .	Nova in cluster Messier 80	11.1	−22 44	5826
. . . .	82 Apr. 14.0	+224.5 E	There is strong evidence of marked inequality of short term, in the period	11.7	−22 42	5830
. . . .	79 Dec. 28.0	+176.7 E		11.7	−22 39	5831
. . . .	81 July 18	+323.6 E	Period 328d.8 will also represent Bessel's observation	16.0	− 7 28	5856
. . . .	. . . .	. . . .	Only one appearance known	16.7	−17 39	5860
. . . .	74 Apr. 30	+307 E		21.2	−12 12	5887
81 Sept. 9	82 Mar. 3.0	+410.5 E	Older data conflict with elements derived from observations 1860 to 1885. Hence period is perhaps not uniform	21.4	+19 7	5889
. . . .	. . . .	. . . .	Irregular; limits of variation from Sawyer's observations	25.4	+42 6	5912
. . . .	70 Feb. 23	+361 E	Very rude approximation to the elements	28.0	−15 55	5928
. . . .	65 Mar. 4.4	+233.8 E *		28.5	−16 57	5931
. . . .	79 June 12	+288.7 E		31.7	+37 32	5950
81 May 23	81 July 15	+180 E?	Safarik has period of 337d. Possibly star has secondary fluctuations, and irregular period.	31.3	+72 29	5948
. . . .	58 June 5.0	+245.9 E	Elements represent Lalande's and the DM. observations	32.4	+66 58	5955
56 Mar. 27	56 Sept. 1	+309.0 E	+55d sin (7°.5 E+100°) Elements provisional	47.3	+15 6	6044
. . . .	. . . .	. . . .	Nova	53.9	−12 45	6083
. . . .	83 Nov. 5	+ {257.5 / 324.0} E	Additional observations only can distinguish which is the correct period	16 54.6	+35 13	6088
. . . .	65 Oct. 21.7	+302.4 E *		17 2.0	−15 58	6132
. . . .	. . . .	. . . .	Irregular. Period two or three months with wide fluctuations from the mean	10.1	+14 30	6181
81 July 17 15 33.52	. . . .	+ 0 20 7 41.6 E—	−0s.0002 E². Algol-type	11.5	+ 1 19	6189
. . . .		40 ?	Period subject to many anomalies. Very rapid secondary oscillations near minimum remarked by Schmidt, confirmed by Schwab	13.6	+33 12	6202
. . . .	. . . .	. . . .	Nova	24.6	−21 24	6268
83 July 8.867	83 July 11.743	+ 7.01185 E *	My investigation gives merely nominal corrections to Schoenfeld's elements, which are therefore retained	41.3	−27 48	6368
83 Aug. 12.268	83 Aug. 15.425	+ 7.59445 E		17 58.6	−29 35	6472
67 Dec. 22.3	68 Mar. 9.3	+164.75 E	+5d sin (7°.2 E+57°.6)	18 5.3	+31 0	6512
86 Sept. 23.51	86 Sept. 25.31	+ 5.7690 E		15.5	−18 54	6573
. . . .	67 Dec. 2.1	+342.3 E *		23.9	+ 6 14	6624
. . . .	. . . .	. . . .	Irregular	25.5	−18 20	6633
83 Aug. 14.658	83 Aug. 17.624	+ 6.74493 E		26.0	−19 12	6636
. . . .	. . . .	. . . .		33.6	+ 8 45	6682
. . . .	. . . .	. . . .	Period three to five months, and irregular	41.0	+ 8 38	6726
86 July 18	86 Aug. 22	+ 71.1 E	Argelander's period with provisional epochs determined from observations 1885–87	42.1	− 5 49	6733
71 Nov. 29.8	71 Dec. 3.8	+ 9.097 E		46.6	−67 21	6760
55 Jan. 6 14 28.7	. . . .	+12 21 46 58.3+ †	+0s.4217 E² −0s.00007 E³ W. M. Reed's elements Secondary minimum about midway	46.4	+33 15	6758
87 Oct. 1	87 Oct. 16	+ 46.0 E	Schoenfeld's period with epochs found from Sawyer's 1887 observations	18 52.3	+43 49	6794

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No.	Sch.	Star	1855.0 R.A.	1855.0 Decl.	Annual Variation		Discoverer	Date	Redness	Magnitude Max.	Magnitude Min.
			h m s	° ′	s	′					
6806	108	S Coronae austr.	18 51 22	−37 8.6	+4.06	+0.08	Schmidt	1866		<9.5	13.0
6811	109	R Coronae austr.	52 8	−37 8.8	4.06	0.08	Schmidt	1866		9.8–11.5	13.2
6812		T Coronae austr.	52 12	−37 9.	4.06	0.08	Schmidt	1876		<9.8	13
6849	110	R Aquilae	18 59 23	+ 8 0.8	2.89	0.09	At Bonn	1856	5.5	6.4– 7.4*	10.9–11.5
6903	111	T Sagittarii	19 7 52	−17 13.2	3.46	0.10	Pogson	1863	6.5	7.6– 8.1*	<11 *
6905	112	R Sagittarii	8 11	−19 33.5	3.52	0.10	Pogson	1858	3.6	7.0– 7.2*	<12 *
6921	113	S Sagittarii	10 57	−19 17.1	3.51	0.10	Pogson	1860	(0)	9.7–10.4*	<13
6984		U Aquilae	21 33	− 7 20.3	3.23	0.12	Sawyer	1886	(0)	6.3	7.3
7045	114	R Cygni	32 56	+49 52.5	1.61	0.13	Pogson	1852	6.0	5.9– 8.0*	<13
7101	115	11 Vulpeculae	41 37	+26 57.7	2.46	0.14	Anthelm	1670		3 *	? *
7106	116	S Vulpeculae	42 27	+26 55.7	2.46	0.15	{Hind / Baxendell}	{1861 / 1862}	3.0	8.4– 8.9*	9.0– 10.0
7120	117	χ Cygni	45 0	+32 33.0	2.31	0.15	Kirch	1686	6.3	4.0– 6.5	13.5
7124	118	η Aquilae	45 5	+ 0 38.2	3.06	0.15	Pigott	1784	(2)	3.5 *	4.7 *
7149		S Sagittae	49 25	+16 15.4	2.73	0.15	Gore	1885	(0)	5.6	6.4
7192		Z Cygni	19 57 21	+49 38.4	1.70	0.16	Espin	1887	(7)	7?	14?
7220	119	S Cygni	20 2 28	+57 34.2	1.26	0.17	At Bonn	1860	5.1	8.8–11.3	<13 *
7234	120	R Capricorni	3 10	−14 41.6	3.37	0.17	Hind	1848	(4)	8.8– 9.7*	<13 *
7242	121	S Aquilae	4 57	+15 11.5	2.76	0.17	Baxendell	1863	0.8	8.4–10.1	10.7–11.8*
7252		W Capricorni	5 57	−22 24.9	3.54	0.17	Peters	1872?		11?	14?
7257	122	R Sagittae	7 27	+16 17.4	2.74	0.18	Baxendell	1859	0.8	8.5– 8.7*	9.8–10.4*
7261	123	R Delphini	7 55	+ 8 39.1	2.90	0.18	{Hencke / Schoenfeld}	{1851 / 1859}	4.0	7.6– 9.0	11.1–12.8
7285	124	P Cygni	12 27	+37 35.1	2.21	0.18	Jansen	1600	(2)	3– 5 *	<6 *
7299	125	U Cygni	15 7	+47 26.3	+1.86	0.19	Knott	1871	9.3	7.0– 8.1	9.4–11.6
7194	126	R Cephei	34 37	+88 41.0	−42	0.21	Pogson	1856	0.5	5? *	10? *
7431	127	S Delphini	36 24	+16 34.2	+2.76	0.21	Baxendell	1860	6.0	8.4– 9.0	10.4–12.0
7428		V Cygni	36 38	+47 37.5	1.94	0.21	Birmingham	1881	8.3	6.8– 9.5	13.5
7437		X Cygni	37 44	+35 4.0	2.35	0.21	Chandler	1886	(0)	6.4	7.2– 7.7
7444	128	T Delphini	38 38	+15 52.5	2.78	0.21	Baxendell	1863	2.0	8.2–10.3	<13 *
7455	129	U Capricorni	40 4	−15 18.8	3.35	0.22	Pogson	1858		10.2–10.8*	<13 *
7456		RR Cygni	41 3	+44 20.4	2.08	0.22	Espin	1888	(6)	8?	9.5?
7459	130	T Cygni	41 24	+33 50.6	2.39	0.22	Schmidt	1864	(1)	5.5? *	6? *
7468	131	T Aquarii	42 17	− 5 40.9	3.17	0.22	Goldschmidt	1861	1.2	6.7– 7.8	12.4–13.0
7483		T Vulpeculae	45 19	+27 42.3	2.54	0.22	Sawyer	1885	(0)	5.5	6.5
7488		Y Cygni	46 16	+34 7.0	2.39	0.22	Chandler	1886	(0)	7.1	7.9
7560	132	R Vulpeculae	57 56	+23 14.9	2.66	0.23	At Bonn	1858	2.0	7.5–8.5 *	12.5–13.6
7571		V Capricorni	20 59 9	−24 30.2	3.50	0.24	Peters	1867		9.5?	14?
7577		X Capricorni	21 0 15	−21 55.8	3.45	0.24	Peters	1872?		11.5?	<14
7609		T Cephei	7 33	+67 54.4	0.82	0.24	Ceraski	1878	6.3	5.6– 6.8	9.5– 9.9
7659	133	T Capricorni	14 0	−15 46.4	3.32	0.25	Hind	1854	(2)	8.9– 9.7*	<13 *
7754		W Cygni	30 34	+44 43.7	2.27	0.27	Gore	1885	(5)	6.1– 6.3	6.7
7787		Cygni	36 1	+42 11.0	+2.36	0.27	Schmidt	1876	(3)	3	13.5
7779	134	S Cephei	36 57	+77 58.2	−0.60	0.27	Hencke	1858	9.1	7.4– 8.5*	11.5 *
7803	135	μ Cephei	39 4	+58 7.0	+1.83	0.27	{Hind / Argelander}	1848	6.2	4? *	5? *
7907		U Aquarii	21 55 24	−17 19.5	3.29	0.29	Peters	1881		10?	14?
7944	136	T Pegasi	22 1 49	+11 49.9	2.93	0.29	Hind	1863	(3)	8.5– 9.3	<13
7994		R Piscis austr.	9 45	−30 19.6	3.43	0.30	Gould	1884		5.7?	<11?
8073	137	δ Cephei	23 48	+57 40.4	2.21	0.31	Goodricke	1784	(2)	3.7 *	4.9 *
8093		R Indi	25 36	−68 2.1	4.40	0.31	Gould	1884		9?	11?
8153		R Lacertae	36 50	+41 36.8	2.65	0.31	Deichmüller	1883	1.8	8.6– 9.3	<13.5
8230	138	S Aquarii	49 20	−21 7.0	3.23	0.32	Argelander	1853	4.0	7.7– 9.1*	<12.5
8273	139	β Pegasi	56 45	+27 17.8	2.90	0.32	Schmidt	1847	(2)	2.2 *	2.7 *
8290	140	R Pegasi	22 59 22	+ 9 45.7	3.01	0.32	Hind	1848	(4)	6.9– 7.9	<13
8373	141	S Pegasi	23 13 13	+ 8 7.6	3.03	0.33	Marth	1864?	1.7	7.3– 8.0	<13
8512	142	R Aquarii	36 19	−16 5.3	3.11	0.33	Harding	1811	4.3	5.8– 8.5*	11? *
8588		R Phoenicis	48 55	−50 35.6	3.14	0.33	Gould	1884		8½?	11?
8597		V Ceti	50 29	− 9 46.1	3.08	0.33	Peters	1879		9.7?	14?
8600	143	R Cassiopeae	23 51 4	+50 34.9	+3.01	+0.33	Pogson	1853	6.5	4.8– 7.0	9.8– 12

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Greenwich Mean Time Min.	Greenwich Mean Time Max.	Period, etc.		Remarks.	1900.0 R.A.	1900.0 Decl.	No.
d h m	d h m	d h m s			h m	° ′	
....	....	6 ?		Schmidt formerly thought period is six days; but his observations since 1881 throw doubt on periodicity	18 54.4	—37 5	6806
....	....	30.5 ?		In west end of a small nebula	55.2	—37 5	6811
....	....	....		4s foll. R Coronae austr.	55.3	—37 5	6812
56 Mar. 23	56 Aug. 7	$+352.3\ E - 0.4\ E^2$		Elements provisional, but rapid shortening of period pretty certain	19 1.5	+ 8 5	6849
....	83 July 7	+384 E			10.5	—17 9	6903
....	69 June 28	+270 E	*		10.8	—19 29	6905
....	69 Nov. 20	+230 E	*		13.6	—19 13	6921
86 Sept. 17.5	86 Sept. 20.0	+ 7.033 E			24.0	— 7 15	6984
....	81 Aug. 7	+425.7 E			34.1	+49 58	7045
....	....	....		Nova	43.5	+27 4	7101
85 Apr. 7.5	85 Apr. 27.8	+ 67.80 E	†	Elements of J. Baxendell, Jr.	44.3	+27 2	7106
....	1763 May 26.76	+406.045 E		$+0^d.00574\ E^2 + 0^d.0000173\ E^3$ Elements provisional.	46.7	+32 40	7120
88 Jan. 4 3 32	88 Jan. 6 12 32	+ 7 4 14 0.0 E		Elements adopted are a correction of +1h 43m of Argelander's epoch 400, and of —4s of his period	47.4	+ 0 45	7124
85 Dec. 1 9 36	85 Dec. 4 9 36	+ 8 9 11.0 E			51.4	+16 22	7149
....	....	....			19 58.6	+49 46	7192
....	65 July 9.2	$+323.3\ E - 0.067\ E^2$			20 3.4	+57 42	7220
....	64 Sept. 3	+347 E	*		5.7	—14 34	7234
70 Jan. 29.2	....	+146.71 E	*		7.0	+15 19	7242
....	85 Sept.	+425 E?	†	Elements from Parkhurst's observations; very uncertain	8.6	—22 17	7252
73 May 1.03	....	+ 70.43 E	*	Type of Beta Lyrae. Secondary minimum follows principal one 34d.9. Evidence of systematic but small deviations from uniform period	9.5	+16 25	7257
....	69 July 13.6	+284.0 E	*		10.5	+ 8 47	7261
....	....	....		Nova	14.1	+37 43	7285
77 Feb. 21.5	77 Oct. 9.6	+461.3 E	†	Elements are Baxendell's	20 16.5	+47 35	7299
....	....	....		Schoenfeld thinks period somewhat less than a year; Schmidt's obsns. confirm; variations generally between 8.0 and 8.5.	19 58.9	+88 50	7194
73 May 10	73 Aug. 22	+277.0 E		Evidence of periodic inequality	20 38.5	+16 44	7431
....	81 June 1	+423 E?		A secondary maximum follows principal one, two or three months	38.1	+47 47	7428
86 Oct. 7 23 56	86 Oct. 13 14 20	+ 15 14 24 E		Bright and faint minima, but not regularly alternating	39.5	+35 13	7437
....	84 Sept. 10.0	+331.9 E		Large deviations from a mean period	40.7	+16 2	7444
....	72 Sept. 19	+203.5 E	*		42.6	—15 9	7455
....	....	....			42.6	+44 30	7456
....	....	....		Period about one year, but variations in some years scarcely noticeable	43.2	+34 0	7459
81 Feb. 15.5	81 May 10.5	+203.3 E			44.7	— 5 31	7468
85 Nov. 1 19 8.6	85 Nov. 2 20 35.0	+ 4 10 29.0 E			47.2	+27 52	7483
88 July 15 19 8	....	+ 1 11 56 48		Algol-type. Large anomalies in period	48.0	+34 17	7488
65 July 19.0	65 Sept. 20.0	+136.9 E+		$20^d \sin (4^\circ E + 90^\circ)$ Schoenfeld had a term $-0.06\ E^2$, but later observations do not confirm it	20 59.9	+23 25	7560
....	86 Sept.	+310 E?	†	Elements from Parkhurst's observations, but uncertain	21 1.8	—24 19	7571
....	85 Sept.	+210 E?	†	" " " " " "	2.8	—21 45	7577
73 Feb. 6	73 Aug. 23	+383.2 E			8.2	+68 5	7609
....	66 Nov. 13.2	+269.4 E	*		16.5	—15 35	7659
84 Oct. 12	84 Dec. 13	+126 E			32.3	+44 56	7754
....	....	....		Nova	37.8	+42 23	7787
80 Sept. 16	81 May 16	+484 E			36.5	+78 10	7779
....	....	+432?		Argelander's period from his observations 1848-64; but those of Schmidt since 1866 do not confirm it	40.4	+58 19	7803
....	....	....		Parkhurst's observations confirm variability, but give no maximum	21 57.9	—17 16	7907
....	69 Nov. 14	+373 E		There is apparently a large periodical inequality of short term	22 4.0	+12 3	7944
....	....	....			12.3	—30 6	7994
88 Jan. 0 15 57.0	88 Jan. 2 6 32.5	+ 5 8 47 39.974	†	Argelander's elements	25.4	+57 54	8073
....	....	....			28.9	—67 48	8093
....	83 Dec. 14	+315 E		Elements very uncertain	38.8	+41 51	8153
....	67 Aug. 11	+279.3 E			51.7	—20 53	8230
....	....	....		Period of one or two months, but the star's light is often nearly constant for many months	22 58.9	+27 32	8273
....	50 Dec. 6	$+378.1\ E + 0^d.17\ E^2$			23 1.6	+10 0	8290
....	77 Dec. 19	+317.5 E			15.5	+ 8 22	8373
....	11 Nov. 30.6	+387.16 E+		$35^d \sin (10^\circ E + 235^\circ)$	38.6	—15 50	8512
....	....	....			51.3	—50 21	8588
....	86 Sept.	+273 E?	†	Elements from Parkhurst's observations, and uncertain	52.8	— 9 31	8597
54 Feb. 10 ?	54 July 9.5	+429.0 E+		$23^d \sin (16^\circ E + 346^\circ)$	23 53.3	+50 50	8600

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(*Continued from page 83.*)

one-tenth of the right-ascension, expressed in time-seconds, for the equinox 1900.0. The precept need not be rigorously applied where two or more variables occur within a few seconds of right-ascension, as it would be better to deviate from the strict order by one or two units than to disturb numbers already affixed.

The numbers of this catalogue have been taken in accordance with these principles; and it is respectfully submitted to the judgement of astronomers whether the system deserves general adoption.

The selection of the stars to be included in the catalogue has been a delicate task, whose difficulty can only be appreciated by those who are familiar with the confusion which so easily creeps into this branch of astronomy, and who have had occasion to undertake the discouraging and thankless labor of bringing order out of the chaos, by the careful and continuous observation necessary to discriminate the actual cases of variability from the numerous pseudo-variables with which the periodicals of the day are filled.

Considering it extremely desirable that no star should be placed in the list, no matter how high the authority on which its variability is asserted, without independent verification, I have had under observation a large number of stars during the last few years with this especial object in view. Mr. SAWYER, also, has similarly followed an extensive list, generally of the brighter class; and I have had the inestimable advantage of access to his results, and of consultation with him as to the propriety of the insertion of many of these stars. Another class of variables, mainly those discovered by Dr. PETERS, which I found considerable difficulty in keeping track of with insufficient optical means, has been assiduously and effectively observed by Mr. H. M. PARKHURST, and his series of observations has been the main reliance for the attestation of the variability of these faint stars. Without the cordial collaboration of these gentlemen the present work would have been much less complete.

Two remarks remain as to the selection of the stars. First, all stars of SCHÖNFELD's catalogue have been retained, although there appears to be perhaps a slight ground for doubt as to one or two of them. Thus, for instance, I have never been able to detect any trace of fluctuation in *δ Orionis*, and I believe SAWYER has a similar experience. But its rejection cannot be justified on this ground alone, in the face of high authority in favor of the variability. Secondly, as to the additions, I have had in mind as a paramount object that our knowledge must be kept clear of confusion, even at the risk of an incomplete statement of it; and that the omission of a star actually variable is not as injurious an imperfection in the catalogue as the insertion of one which is not so. Therefore, where a reasonable doubt has appeared to exist as to any star, it has been excluded until it could be further examined. A list of some of these cases is given below, with a succinct statement of the reasons for their omission.

NOTES RELATING TO STARS NOT INSERTED IN THE CATALOGUE.

Positions for Equinox 1855.0.

$1^h\ 18^m\ 31^s$ $-4°\ 40'.9$

GOULD thinks certainly variable. SAWYER's observations show no trace of fluctuation; his numerous estimates, ranging over a long period, all lie between 6.5 and 6.8.

$1^h\ 27^m\ 11^s$ $+11°\ 48'.6$

In BORRELLY's list, *Bull. Astron.* II. GORE thought near maximum 1885 Nov. 30, but observed only slight variability in 1886. SAWYER thinks it is not variable.

$1^h\ 33^m\ 0^s$ $-7°\ 21'.6$

SAFARIK thinks variable from 8.4 to 9.2, from his observations 1887 Oct. to 1888 Feb. 19; period probably longer than four months.

$3^h\ 41^m\ 9^s$ $+35°\ 16'.7$

KAM suspects variability; see *A.N.* CX, 181. By my observations 1888 April 2, and Aug. 11, it must have been below 11.5 or 12.0.

$3^h\ 45^m\ 26^s$ $+7°\ 20'.6$

GOULD thought certainly variable, from 6.8 to 8.0. My observations seem to favor fluctuation, but I desire to continue them before pronouncing definitely.

$4^h\ 48^m\ 48^s$ $-16°\ 39'.3$

GOULD's *R Eridani.* SAWYER's observations do not show any change of light.

$4^h\ 53^m\ 11^s$ $-12°\ 45'.1$

GOULD's *S Eridani.* SAWYER's observations do not show any change of light.

$5^h\ 21^m\ 48^s$ $-4°\ 49'.1$

SAFARIK thinks variable by several magnitudes. Near *S Orionis.* See *V.J.S.* 1884, p. 145.

$5^h\ 22^m\ 22^s$ $-1°\ 11'.7$

GOULD says it appears to be variable from $4\frac{3}{4}$ to 6. The star is very red. GORE thinks his observations confirm variability.

$5^h\ 27^m\ 10^s$ $+10°\ 8'.1$

GOULD thinks variable, from discordance of Cordoba estimates, 5.7 to 6.7. Other observations do not appear to confirm.

$6^h\ 12^m\ 54^s$ $+47°\ 43'.5$

ESPIN suggests variability. Not yet confirmed.

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7h 21m 3s —11° 15′.9

ESPIN asserts variability and assigns a period of fourteen days; in which he is confirmed by JACKSON. But SAWYER, YENDELL and myself have carefully followed it without detecting the slightest change. I consider the constancy of its light practically demonstrated.

7h 35m 15s —31° 19′.6

GOULD's *R Puppis*. Neither SAWYER's observations nor mine show any unsteadiness of lustre.

7h 43m 11s —40° 17′.5

GOULD's *T Puppis*. SAWYER has followed the star as closely as the low altitude of the star in this latitude will permit, and has yet found no confirmation.

8h 1m 34s +19° 50′.0

PETERS announced as variable, *A.N.* CII, 147. My observations do not confirm, but are indecisive. PARKHURST thinks that, if variable, it may possibly be of *Algol*-type, but the evidence of change by his observations is also slight.

10h 0m 42s —51° 29′.0

GOULD's *R Velorum*. As he gives no period, and there are no other confirmatory observations, I have considered it safer not to insert it in the catalogue.

10d 49m 30s —59° 44′.8

GOULD's *T Carinae*. UPTON's comparisons in 1883 seem to confirm, but the observed limits of variation are so small that I think more evidence is essential before classing it with the known variables.

12h 26m 47s —22° 35′.7

β Corvi. SAWYER's observations seem to show clearly the variation of this star, but he agrees with me that it is better to await confirmation before inserting in the catalogue. See *A.N.* CXI, 271.

13h 26m 58s —12° 28′.0

SCHMIDT thought variable, and GOULD that the Cordoba estimates confirmed it, and the latter suggested the name *Y Virginis*. SAWYER, however, has eight observations, in different years, all within the narrow range 6.0 to 6.25; and he is very skeptical as to its variability. The star is very difficult to observe, which may account for the discordances. See my note *H.C.O. Annals*, XIV, Part II, p. 456, star No. 2293.

14h 56m 20s —68° 9.4

GOULD's *T Triang. austr.* He says it is variable between 7.0 and 7.4, in a period which differs but little from a mean solar day. The assigned limits are so narrow that confirmation by other observations is desirable, to justify its insertion in the catalogue.

15h 35m 17s —10° 27′.7

WEISS says it is variable from 7.0 to 8.8, in a period of about four months. My observations yet do not enable me to confirm the variation certainly.

15h 37m 55s —20° 40′.8

PETERS announced the variability, *A.N.* CII, 147. My observations furnish no decisive evidence in the matter.

16h 20m 47s —19° 11′.5

PETERS announced the variability, *A.N.* XCIX, 120. My observations indecisive. PARKHURST says he has never been able to see this star, and he mentions it, in a private letter, as one of the three stars of PETERS which he has not yet been able to confirm.

18h 1m 54s +28° 44′.4

o Herculis. See my note, *H.C.O. Annals*, XIV, Part II, p. 464, No. 3048.

19h 9m 53s —19° 19′.4

SAFARIK thinks his observations show variability between 9.4 and 10.1. Near *S Sagittarii*, with which he confounded it, when first undertaking to observe the latter.

19h 15m 13s +17° 23′.1

ESPIN's suggestion of variability is very likely correct, although my observations do not yet confirm it certainly.

19h 26m 15s +17° 26′.0

I have given the evidence which, it seems to me, render the variability almost certain, in the *Science Observer*, Nos. 43–44, Vol. IV. It lies 0s.7 foll., north 2′.2, DM. +17.3997. I have looked for it at least fifty times unsuccessfully, when it must have been below 13.

19h 27m 13s —25° 2′.0

GOULD thinks variable between limits wider than 5.3 to 6.7. SAWYER has three observations in 1882, 1886 and 1887, giving accordantly 5.9 or 6.0.

19h 55m 18s +30° 25′.6

ESPIN suggests variability. Not yet confirmed.

20h 5m 3s +47° 25′.4

ESPIN alleges variability, 7.7 to 8.9. My estimates so far perfectly accordant, 8.9 or 9.1.

20h 8m 7s +38° 17′.4

ESPIN alleges variability, 6.6 to 8.0. My observations indicate that there is some possibility of change, but the star is close to another, and difficult to adjudge properly.

20h 8m 37s —21° 45′.6

SAFARIK thinks his observations show fluctuation of six-tenths of a magnitude. SECCHI had previously marked it "var.?" in his *Prodromo*.

20h 23m 34s +39° 29′.9

ESPIN alleged variability, 7.9 to 9.2; afterwards, in 1886, found it practically invariable.

20h 38m 50s +17° 34′.0

D'ARREST suspected variability, and my observations in 1886 and 1888, lead me to believe it may possibly be subject to it. GORE asserts a period of perhaps 111 days.

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$21^h\ 1^m\ 37^s \quad +47°\ 3'.9$

Espin alleges as variable from 4.7 to 6.0, in long or irregular period; but my observations, some of them nearly coincident in date with his, contradict them and give no support to the idea of fluctuation. Sawyer also thinks the star is constant. The star is very red, and difficult to observe; one of those likely to deceive an inexpert or uncritical observer.

$22^h\ 28^m\ 17^s \quad -8°\ 20'.8$

Hind suspected the variability, and Schönfeld was inclined to think it not improbable. See *A.N.* LXIV, 176. Also *Nature*, XXX, 346. I am observing the star, but cannot yet say anything definite with regard to it.

$23^h\ 39^m\ 0^s \quad +2°\ 40'.8$

Gould was inclined to suspect variability, and other evidence seems to accord with the idea. See my note *H.C.O. Annals*, XIV, Part II, p. 474, No. 4198. My observations in 1885 and 1886 do not confirm, and I am strongly of opinion that the red color is responsible for much, if not all, of the observed contradiction in the estimates, made under different circumstances.

$23^h\ 53^m\ 54^s \quad +59°\ 33'.1$

Secchi marked this as "var.?" My own observations in 1875 led me independently to suspect it, at first, but I afterwards concluded that the trouble lay entirely in the difficulty of estimating properly this very red star so close to a bluish companion.

In assigning Argelander's letters the rubrics of Schönfeld and Winnecke have been observed. In *Virgo* and *Cygnus* the alphabet is exhausted, and the extension of the notation under the suggestion of Hartwig, favored by Schönfeld, is begun by designating No. 5037 of the catalogue as *RR Virginis*, and No. 7456 as *RR Cygni*.

OBSERVED MAXIMA OF TELESCOPIC VARIABLES,

By PAUL S. YENDELL.

S Coronae, 1888.

A projection of the light-curve from a series of 32 observations of this variable, extending from March 17 to June 9, 1888, indicates a maximum about April 21. No record of estimates of magnitude has been kept, but on July 14 it was estimated to be about $8^M.5$.

R Leonis, 1888. 3493

34 observations of *R Leonis* were secured between March 7 and June 18, 1888, and a maximum is indicated about June 1; but little weight is attached to this determination, as the observations after maximum are few, and were obtained with difficulty, on account of the approach of the star to the sun. The maximum was a tolerably bright one, the star at this phase being = 18 *Leonis*, or 6.2 magnitude. The observations were begun with my $4\frac{1}{4}$-inch Clacey telescope, power 36, and continued from May 7 with a field-glass, a careful comparison of observations with both at this date establishing a definite connection in the light-scale.

S Ursae Majoris.

Observations of this star extended from March 17 to July 14, numbering in all 23, and showing a maximum on June 15. When first seen it was estimated to be of the 11 magnitude. The increase was irregular, being interrupted by sharp fluctuations, and rising after June 1 quite suddenly to the maximum, at which point its light is estimated to have been about 7.5 magnitude. The decrease has been rapid and apparently regular; at the last observation the star's light was estimated as 8.5 magnitude. All the observations were made with the $4\frac{1}{4}$-inch Clacey glass.

Dorchester, Mass., 1888 *July* 16.

NEW COMET, 1888 *e* (*BARNARD, September 2*).

A dispatch from Prof. E. S. Holden announces the discovery of a comet at the Lick Observatory, by Prof. E. E. Barnard. Its position September $3^d.023437$ Greenwich M.T. was following $58^s.07$, south 8′ 1″, the DM. star 11°.1377. It is described as circular; one minute in diameter; eleventh magnitude; with a tolerably well defined nucleus. No decided motion observed in twenty minutes.

An approximate reduction of the observation gives the comet's place about,

$$\alpha = 6^h\ 52^m\ 17^s \qquad \delta + 10°\ 59'.3.$$

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OBSERVATIONS OF *HYPERION*,

By A. HALL.

[Communicated by the Superintendent of the Naval Observatory.]

	Date		Washington M.T.	Position Angle	Washington M.T.	Distance	Wt.	Remarks
			h m	°	h m	″		
1886	Oct.	2	15 47.9	250.42	15 55.9	200.92	2	
	"	3	16 12.8	241.20	16 20.3	173.11	3	
	"	4	16 12.8	228.15	16 19.8	141.15	2	Hazy, satellite faint
	"	5	16 36.7	207.00	16 44.2	111.05	2	Hazy, and satellite very faint
	"	6	16 17.7	175.91	16 27.7	95.78	2	Very faint
	"	7	16 29.2	142.80	16 42.7	109.16	2	Hazy, and satellite extremely faint
	"	8	16 17.2	121.74	16 23.2	139.63	3	Faint, foggy
	"	9	15 42.1	109.05	15 51.1	174.90	3	Fog, and satellite extremely faint
	"	10	16 10.6	99.90	16 17.6	203.33	3	Faint
	"	11	16 24.1	92.65	16 30.6	225.11	3	Faint, moonlight
	"	12	16 19.5	86.22	16 27.5	230.05	2	Very faint
	"	15	17 17.9	61.38	17 25.4	154.18	3	Excessively faint for *s*; moon and twilight
	"	16	16 13.9	42.60	16 22.4	109.52	3	
	"	21	15 23.3	266.85	15 32.8	216.36	3	
	"	22	15 37.8	260.00	15 44.3	223.56	3	
	"	23	16 10.2	252.98	16 18.7	214.32	4	
	"	24	15 48.2	244.80	15 53.7	188.43	4	Faint, hazy
	Dec.	3	10 52.2	264.63	10 58.7	237.79	2	
	"	7	10 54.2	228.55	11 1.2	159.30	2	
	"	8	10 56.7	208.54	11 3.2	124.86	2	
	"	16	10 27.6	79.35	10 34.6	243.17	2	
	"	20	11 18.6	351.01	11 23.1	84.73	4	Faint
	"	21	10 40.0	306.78	10 47.0	116.88	2	
	"	27	10 25.4	242.65	10 32.9	202.36	2	Clouds
1887	Jan.	3	9 10.4	101.57	9 15.4	225.41	2	
	"	18	9 37.2	232.00	9 44.7	173.43	2	
	"	18	9 52.2	139.98	9 57.2	46.14	2	*Titan-Hyperion*
	"	22	8 25.6	128.52	8 34.6	147.22	3	Faint, hazy
	"	24	8 43.5	102.79	8 49.5	220.99	2	Faint
	"	24	8 59.0	163.98	9 4.5	53.45	2	*Titan-Hyperion*
	"	25	9 16.5	94.50	9 20.5	244.90	2	Faint, sky hazy
	"	25	9 29.0	140.38	9 33.5	74.13	2	Faint, *Titan-Hyperion*
	"	26	9 8.5	87.82	9 14.0	256.50	3	Windy
	"	26	9 21.5	120.68	9 29.5	106.96	3	Windy, *Titan-Hyperion*
	"	27	8 56.0	81.45	9 3.5	249.17	3	Faint
	"	30	8 8.9	46.22	8 15.9	133.07	2	
	Feb.	11	8 36.7	156.25	8 42.2	115.60	2	Very windy
	"	12	8 10.2	130.92	8 14.7	142.39	3	
	"	13	8 26.1	114.52	8 31.1	179.74	3	
	"	16	9 14.1	88.75	9 20.6	250.49	3	
	"	22	8 6.0	325.15	8 11.0	98.87	3	
	"	24	7 55.0	278.65	8 0.0	188.45	2	Windy
	"	27	7 27.9	254.72	7 34.4	228.83	2	Faint, hazy and windy
	"	28	6 59.4	246.12	7 5.9	208.01	3	
	Mar.	1	7 9.4	235.22	7 14.4	176.28	3	Faint
	"	2	8 13.8	218.02	8 19.3	140.15	2	Very faint, hazy
	"	10	8 14.1	83.25	8 21.1	240.08	3	
	"	11	7 8.1	76.42	7 13.1	221.26	2	
	"	12	6 57.1	67.25	7 2.6	187.91	2	
	"	22	7 32.9	237.18	7 38.4	176.64	2	Faint, windy
	"	23	7 48.9	222.32	7 54.4	141.17	3	
	"	23	8 5.9	127.28	8 10.9	55.16	3	*Titan-Hyperion*
	"	24	8 23.0	198.62	8 31.5	113.04	2	Very faint
	"	24	8 40.0	119.20	8 46.5	48.48	2	Extremely faint, *Titan-Hyperion*
	"	25	7 20.9	167.70	7 26.4	106.32	3	Faint

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	Date	Washington M.T.	Position Angle	Washington M.T.	Distance	Wt.	Remarks
		h m	°	h m	″		
1887	Mar. 25	7 34.9	121.90	7 42.4	39.76	3	*Titan-Hyperion*
	" 29	7 54.7	98.28	8 1.7	214.06	2	Very faint, windy and moonlight
	" 29	8 15.2	148.08	8 21.2	49.68	2	Very faint, *Titan-Hyperion*
	Nov. 21	15 21.3	81.25	15 33.3	218.84	3	
	" 22	16 4.3	74.57	16 10.3	192.57	2	Faint, haze
	Dec. 22	11 41.8	259.02	11 48.3	256.56	2	
1888	Jan. 11	10 12.9	265.69	10 18.4	253.35	2	
	" 18	9 47.8	170.75	9 52.8	97.98	2	
	" 19	9 54.6	135.60	10 1.6	115.18	2	Faint
	" 21	9 27.3	103.69	9 33.3	193.82	3	
	" 30	9 0.7	285.11	9 8.7	162.33	2	Extremely faint for *s*; haze
	Feb. 1	9 37.2	267.75	9 43.2	246.94	3	
	" 2	9 9.7	262.27	9 17.2	260.38	3	Faint
	" 8	8 56.1	182.82	9 2.1	100.15	2	Very faint
	" 13	9 0.5	90.65	9 11.0	234.70	3	Faint
	" 14	8 49.9	84.12	9 9.4	237.86	2	
	" 15	8 4.9	77.69	8 9.9	219.58	2	
	" 16	10 24.9	67.28	10 31.4	175.79	2	
	" 18	8 0.4	16.62	8 7.4	80.41	3	Very faint
	" 28	8 46.7	220.15	8 53.7	135.09	3	Strong moonlight
	Mar. 6	8 6.5	86.75	8 12.5	233.79	3	
	" 7	8 8.0	80.02	8 14.0	222.51	2	
	" 8	8 10.0	71.80	8 16.5	191.45	2	
	" 9	7 57.0	59.32	8 2.5	145.21	3	
	" 14	7 18.5	272.32	7 24.5	215.47	2	Windy and bad images
	" 15	7 34.4	265.98	7 40.4	241.90	3	
	" 17	8 22.9	254.05	8 28.4	238.97	3	
	" 18	8 15.9	247.45	8 22.4	215.98	3	
	" 30	7 22.6	65.60	7 29.1	158.91	3	Faint
	Apr. 1	7 28.0	1.82	7 35.0	73.51	2	Faint
	" 2	8 11.0	308.92	8 18.0	99.24	2	
	" 3	8 11.9	286.58	8 17.9	149.70	3	
	" 4	7 47.4	275.60	7 54.4	196.02	3	Faint
	" 6	7 35.9	262.45	7 45.9	238.00	2	
	" 7	7 50.3	256.60	7 59.8	236.96	3	
	" 7	8 8.3	223.85	8 14.3	57.62	3	*Titan-Hyperion*
	" 8	7 44.8	250.72	7 51.8	218.00	2	Faint
	" 8	7 58.8	209.60	8 6.3	39.34	2	Faint, *Titan-Hyperion*
	" 12	7 58.2	185.18	8 5.7	95.14	3	

NOTE. — The angles and distances are referred to the center of *Saturn*, except those marked *Titan-Hyperion*, in which *Hyperion* is referred to *Titan*. The observations have been corrected for differential refraction. The weights refer to the condition of the images, and are estimated on a scale of 5; 1 denoting extremely poor, and 5 perfect. In nearly every case four settings of the circle were made for the angle, and four single distances were measured for the resulting value. In the Remarks, *s* refers to the distance.

1888 *August* 2.

THE SPECTRUM OF *R CYGNI*.

A dispatch in the *Science Observer* code, received August 27 from Lord CRAWFORD'S Observatory, states that the spectrum of the variable star *R Cygni* was found to contain bright lines, according to observations by ESPIN at Wolsingham, on August 13 and 22, and at the Dun Echt Observatory on August 26.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

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PHYSICAL OBSERVATIONS OF *MARS* DURING THE OPPOSITION OF 1888, AT THE LICK OBSERVATORY,

BY EDWARD S. HOLDEN.

The opposition of *Mars* took place April 11, 1888. The Lick Observatory was transferred to the University of California on June 1. Previous to this time Mr. KEELER was the only member of the astronomical staff at the Observatory, and he utilized all opportunities for observation in making a series of measures of the satellites of *Mars*, which have already been printed in the *Astronomical Journal*.

It was not until July 16, however, that the work of the machinists and others on the dome and elevating floor was sufficiently advanced to allow of regular observations.

On every suitable night since that time at least one drawing of *Mars* has been made, either by myself, Mr. SCHAEBERLE, or Mr. KEELER. A list of all the drawings made follows:

E. S. H.	J. M. S.	J. E. K.
h m	h m	h m
	July 16 9 00 P.S.T.	
	17 9 25 "	
July 18 8 35 P.S.T.	18 8 50 "	
19 8 25 "	19 9 00 "	
20 – "	20 – "	
	23 8 45 "	July 23 8 45 P.S.T.
24 8 13 "	24 8 45 "	24 8 45 "
25 7 45 "	25 7 50 "	25 8 00 "
25 8 20 "	25 8 40 "	
26 8 10 "	26 9 10 "	26 8 40 "
26 8 21 "		
27 8 00 "		27 8 15 "
29 7 28 "	29 7 52 "	29 8 20 "
31 7 24 "		
Aug. 1 7 22 "	Aug. 1 7 52 "	
2 7 23 "	2 8 00 "	
5 7 28 "	5 8 20 "	
5 7 40 "		
8 7 33 "	8 7 35 "	
9 7 38 "	9 8 03 "	
9 8 30 "		
10 7 30 "	10 8 00 "	

Plate I gives a series of these drawings arranged in the order of longitude of the central meridian of each drawing. I desire to express my obligation to Mr. MARTH for the excellent ephemerides of *Mars* which have regularly appeared from his hand, and which have done so much to stimulate and to systematize such observations as these.

The drawings themselves are simple diagrams, as accurate as they could be made by eye estimations alone. Circumstances did not permit of more exact determinations of the positions of the various markings of the disc. No attempt at pictorial representation is made.

Plate II gives seven drawings of *Mars* made by me with the 26-inch equatorial at Washington in 1875, 1877 and 1879. The first five of these were redrawn by Monsieur F. TERBY, and printed in *Mémoires Couronnés de l'Academie Royale de Belgique*, tome XXXI (1880); but they are comparatively unknown in America, although they are interesting as confirming some of the discoveries of Professor SCHIAPARELLI. The other two figures are printed for the first time.

The twenty-one drawings of Plate I (1888) form a reasonably complete representation of the disc when the unfavorable circumstances of the opposition are considered. All of them were made when the disc of the planet was less than 9″, and when the zenith distance was nearly 60°; and all of them were made in the early evening before the large objective was cooled to the temperature of the surrounding air. Magnifying powers of 350 to 700 diameters have been employed according to the various conditions of vision.

The inner satellite (*Phobos*) was seen on July 18, when it was only .22 of its brilliancy at mean opposition, and only $\frac{1}{8}$ as bright as at the time of discovery by Professor HALL.

It is very unfortunate that the great telescope was not available for these observations until three months after opposition, and that it will be necessary to wait until 1890 to form a map of the planet based upon our own work. Still it appears to me that the drawings here given, present important evidence relating to the canals of M. SCHIAPARELLI, and to the submergence of the "continent" *Libya* reported and confirmed by M. PERROTIN in May last.

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With regard to the canals it appears that we have not seen any of them double, although many of the more important have been sketched as broad bands covering the spaces on M. SCHIAPARELLI's map which are occupied by pairs of canals and by the space separating the members of each pair.

With regard to the "continent" *Libya* the observations here show nothing before July 16. After that date we have eight drawings (July 31, July 29, July 27, July 27, July 27, July 26, July 25, July 25, July 26), which exhibit this marking in various aspects, all of which are in substantial agreement with each other, and each of which differs materially from the observations made at Nice during April, and May, as given in *L'Astronomie* for June 1888, page 214.

M. PERROTIN says that *Libya*, which was plainly visible two years ago, "does not exist to-day" (April and May, 1888).

The eight drawings above mentioned show it, however, in essentially the form in which it was drawn by M. SCHIAPARELLI in 1877 and 1878, not to speak of later drawings. It is much to be regretted that the series of drawings at the Lick Observatory begins at so late a date; but so far as the evidence of our work goes, it may be said that during this opposition we have seen no double canal, and do not find any important changes in the "continent" *Libya*. At the same time no one is more sensible than myself of the highly unfavorable conditions under which our work on *Mars* has been done. We have, however, seen enough of the working of the great telescope on *Mars* and on other objects to know that its powers are amply adequate under favorable conditions; and we confidently expect the next two oppositions to furnish the most conclusive evidence on these highly interesting questions. No more could have been done here during this year than was done, but the opportunities of even a single favorable opposition, diligently improved, will suffice to perfect our knowledge of the topography of *Mars* to a most important degree, and two such should present us with a map of the planet, which may fairly be called complete.

Mount Hamilton, 1888 *August* 17.

OBSERVATIONS ON *MARS*,

BY A. HALL.

[Communicated by the Superintendent of the Naval Observatory.]

OBSERVATIONS OF THE SATELLITES.

Date	W.M.T.	p	Δp	W.M.T.	s	Δs	Remarks
			Deimos.				
	h m	°	°	h m	″	″	
1888 Mar. 30	12 16.1	122.91	— 0.53	12 27.1	50.51	—0.10	Faint
Apr. 4	12 41.4	118.11	+ 1.02	12 52.4	50.21	+0.21	Haze, very faint
6	11 19.1	304.13	+ 0.26	11 28.4	52.81	—0.24	
8	10 4.3	130.71	— 0.54	10 12.3	51.26	+0.18	
11	10 42.2	296.03	— 0.27				
13	10 10.7	125.97	— 0.40	10 18.2	52.78	+0.52	
16	11 13.1	292.27	+ 0.43	11 22.6	49.67	—1.15	Very faint
20	9 0.5	306.51	+ 0.26	9 7.5	53.73	—0.89	Faint
25	9 19.4	303.31	— 0.55	9 27.9	52.81	+0.02	Extremely faint
May 2	8 53.2	127.65	— 0.11	9 1.3	51.55	—1.10	Faint
5	9 39.7	292.61	+ 0.02	9 48.7	48.69	—0.84	Extremely faint
			Phobos.				
	h m	°	°	h m	″	″	
1888 Apr. 7	11 21.3	124.6	+ 5.76	11 29.3	20.70	—0.46	Very faint
8	10 44.3	128.9	+11.74				Extremely faint
11	11 5.	(297.)	(+19.59)				Estimated, clock fails
26	10 31.	301.5	+ 6.58				Extremely faint

NOTE. — The residuals (C—O) were found by comparing with MARTH's ephemeris. *Phobos* was barely visible, and the observations were made with difficulty. Only the first is of much value. The observations have been corrected for differential refraction and the figure of the disk.

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A STUDY IN THE ELEMENTS OF ENCKE'S COMET,

BY ORRAY T. SHERMAN.

In the *Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg*, VII^e Série, T. XXVI, XXXII and XXXIV, VON ASTEN and BACKLUND have given the elements of ENCKE'S comet for its successive appearances from 1819–1885 inclusive. The condition in which the theory of the well known acceleration is left by the final paper may perhaps best be shown by the following extract:

"Die Frage, welcher der Grund, zu der hier constatirten Veränderung in der Bewegung des ENCKE'schen Cometen sein kann, gehört eigentlich nicht hierher; jedoch darf das nicht unerwähnt bleiben, was deutlich auf der Hand liegt. Die Acceleration der mittleren Bewegung kann nur in zweierlei Weise erklärt werden. Entweder wird sie von einem widerstehenden Mittel erzeugt, oder sie ist in Zersetzungsprocessen des Cometen begründet. Im ersten Falle muss die Oberfläche des Cometen gegen welche das widerstehende Mittel wirkst, sich Verändert haben; denn es ist sehr unwahrscheinlich, dass das Mittel die Hälfte seiner Widerstandsfähigkeit im Laufe von 3 Jahren verloren hätte, um dann wieder constant zu bleiben. Im zweiten Falle muss eine Verhältnissmässig abrupte Veränderung im dem Zersetsungsprocessen stattgefunden haben. In beiden Fällen hat man also mit einer relativ rasch vor sich gegangen, physischen Veränderung des Cometen zu thun."

The following paper displays the grounds upon which the condition of the medium has varied. It will be seen that, in place of changing by half its amount, successive transits, one of which occurred near the end of a spot-cycle, while the other occurred at the beginning of the following cycle, might have found the disturbing forces nearly ten times greater in the second than in the first case.

The following table presents the osculating elements as derived from the memoirs quoted above. The first eight columns give the osculating elements of the comet, and the ninth the approximate relative sun-spot frequency for the date. The observations above the horizontal line are derived from VAN ASTEN'S series, and those below from BACKLUND'S. The letter i indicates that the sun-spot cycle is increasing, while the letter d implies that the cycle is decreasing.

ELEMENTS OF ENCKE'S COMET.

Osculation and Epoch B.M.T.	i	Ω	π	α	μ	M	Spot Number
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	″	° ′ ″	
1819 Jan. 27.28	13 36 56.01	334 33 17.53	156 59 46.78	58 3 42.47	1076.938309	359 59 49.68	26.6 d
*1822 May 24.03	13 20 21.00	334 25 8.79	157 12 19.19	57 37 8.59	1069.535612	0 0 32.12	3.9 d
*1825 Sept. 16.33	13 21 28.05	331 27 29.87	157 15 5.65	57 39 51.81	1070.338311	0 0 19.37	20.7 i
*1829 Jan. 9.75	13 20 38.42	334 29 32.07	157 18 28.05	57 38 10.04	1069.863241	359 59 28.11	67.2 i
*1832 May 4.03	13 22 12.45	334 32 9.77	157 21 35.95	57 43 13.93	1071.347675	0 0 8.26	26.3 d
*1835 Aug. 26.33	13 21 18.96	334 35 0.38	157 24 4.04	57 40 48.06	1070.770606	359 58 46.85	59.0 i
*1838 Dec. 19.03	13 21 32.02	334 36 42.27	157 27 38.97	57 41 43.13	1071.143915	359 59 42.69	93.7 d
*1842 Apr. 12.03	13 20 30.07	334 39 11.20	157 30 1.51	57 39 13.89	1070.621030	359 59 32.35	27.0 d
*1845 Aug. 9.63	13 7 38.87	334 19 36.60	157 44 54.84	57 56 15.83	1075.318179	359 59 51.94	38.3 i
1849 Feb. 19.0	13 8 41.03	334 22 17.56	157 47 48.03	57 58 48.78	1076.433820	25 22 49.12	100.0 d
1852 June 23.0	13 7 49.67	334 23 42.28	157 51 5.57	57 57 6.68	1076.369543	29 58 31.26	52.7 d
1855 Oct. 6.0	13 8 4.65	334 26 16.15	157 53 12.41	57 57 56.55	1076.523551	28 59 5.35	6.0 d
1859 Jan. 28.0	13 4 17.25	334 28 0.63	157 57 0.54	57 49 17.90	1073.963016	30 18 31.61	90.3 i
1862 May 22.0	13 4 57.32	334 30 57.93	158 1 7.14	57 51 17.64	1074.404629	31 15 6.32	61.0 d
1865 Aug. 19.0	13 3 51.20	334 32 38.55	158 3 48.91	57 48 43.22	1073.871812	24 46 12.45	31.4 d
1868 June 14.0	13 6 40.60	334 31 33.68	158 11 18.25	58 7 1.08	1079.029196	332 13 46.68	36.8 i
1871 July 15.0	13 7 20.70	334 34 19.37	158 13 23.32	58 8 22.80	1079.824622	309 59 5.90	113.8 d
1874 Oct. 27.0	13 7 16.56	334 36 53.97	158 17 22.32	58 8 48.35	1079.434257	309 41 14.77	43.1 d
1871 July 15.0	13 7 24.14	334 34 24.99	158 13 13.60	58 8 20.70	1079.778015	309 57 25.20	113.8 d
1874 Oct. 27.0	13 7 20.01	334 36 59.55	158 17 12.66	58 8 47.26	1079.327541	309 37 29.35	43.1 d
1878 Apr. 24.0	13 6 36.95	334 19 13.22	158 19 31.60	58 7 11.27	1079.448241	332 3 10.35	3.8 d
1881 July 2.0	12 53 7.09	334 34 28.21	158 29 40.24	57 42 53.21	1072.089099	319 23 59.00	54.2 i
1885 Dec. 18.0	12 54 0.76	334 36 56.32	158 32 45.21	57 45 18.63	1073.012513	336 15 11.09	50.3 d

* The equinox corresponds to the epoch in those returns marked with a *; in other cases the equinox is for the beginning of the year.

The successive differences which this table presents are thought to be, in part at least, the record of perturbing forces still unrecognized and perhaps irregular in their action. The following table presents the first differences of the series for i, π, Ω, α and μ, after i, π, Ω have been referred to a constant plane. The values are then arranged with regard to their position in the sun-spot cycle at the date of the later epoch.

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First Differences in the Elements of Encke's Comet.

Year	Spot No.	μ	α	☊	π	i
		″	′ ″	′ ″	′ ″	′ ″
1859	i 90.3	—2.5606	— 8 38.65	+ 0 13.2	+ 1 2.4	— 3 47.4
1829	67.2	—0.4745	— 1 40.77	— 0 41.4	+ 0 36.7	— 0 49.6
1835	59.0	—0.5771	— 2 25.87	+ 0 6.0	— 0 17.6	—13 28.9
1881	54.2	—7.3926	—24 19.72	— 7 29.4	+ 7 19.0	— 0 53.5
1845	38.3	+4.6971	+17 1.96	—22 28.0	+11 7.6	—12 51.2
1868	36.8	+5.1574	+18 17.86	+ 0 2.9	+ 4 43.6	+ 2 49.4
1825	20.7	+0.8027	+ 2 43.21	— 0 22.6	+ 0 10.8	+ 1 7.1
1878	i 3.8	+0.1140	+ 7 23.60	— 0 29.4	— 0 26.9	— 0 42.5
1822	d 3.9	—7.4070	—13 23.80	—10 52.3	+ 9 45.7	—16 35.0
1855	6.0	+0.1541	+ 0 49.90	— 0 59.2	— 0 38.9	+ 0 15.0
1832	26.3	+1.4845	+ 5 3.89	— 0 5.9	+ 0 22.2	+ 1 34.3
1842	27.0	—0.5229	— 2 29.24	— 0 14.9	— 0 23.2	— 1 2.0
1865	31.4	—0.5328	— 0 54.42	— 3 48.5	— 0 3.9	— 1 6.1
1874	43.1	—0.4430	+ 0 27.40	— 0 29.7	+ 1 13.3	— 0 4.1
1885	50.3	+0.9525	+ 2 20.30	— 0 10.3	+ 0 13.2	+ 0 50.1
1852	52.7	—0.0643	— 1 42.10	— 1 18.9	+ 0 31.9	— 0 52.7
1862	61.0	+0.4416	+ 2 19.74	— 1 3.0	+ 1 20.9	+ 0 50.1
1838	93.7	+0.6733	+ 0 35.07	— 0 14.9	+ 0 49.2	+ 0 13.1
1849	100.0	+1.1156	— 4 27.02	— 2 6.8	+ 0 7.6	+ 0 62.5
1871	d113.8	+0.7474	— 6 34.00	— 0 9.0	— 0 40.2	+ 0 46.1

Remembering Sporer's result that one sun-spot cycle begins before the preceding ends, it will not be difficult to recognize, by simple inspection of the above table, that the large differences belong almost entirely to the period of increasing sun-spots, while the period of decreasing spots has but slight effect. The true relation is, however, more readily seen by the following table, formed from the preceding one by taking the means of those results whose sun-spot numbers are nearly the same.

Mean Differences in the Elements of Encke's Comet.

Spot No.	μ	α	☊	π	i
	″	′ ″	′ ″	′ ″	′ ″
i 90.3	—2.5605	— 8 38.63	+0 13.16	+1 2.44	—3 47.4
60.1	—2.8147	— 9 28.79	—2 11.87	+2 32.73	—5 4.0
31.9	+3.5524	+12 41.0	—7 35.91	+5 20.68	—2 58.25
i 2.0	—2.3796	— 1 43.4	—4 6.87	+2 53.32	—5 51.9
d 31.9	—0.0047	+ 0 51.57	—1 9.77	—0 2.29	—0 11.25
54.7	+0.4433	+ 0 56.0	—0 50.75	+0 49.85	+0 10.85
d102.5	+0.8454	— 3 8.65	—0 8.88	+0 5.59	+0 40.53

It will be seen at a glance that those elements which determine the place of the orbit suffer fairly regular and smooth changes during the sun-spot cycle, having a maximum of disturbance in the neighborhood of sun-spot number 32; while those which lie in the plane of the orbit, though presenting regular variations for other portions of the cycle, have their curves badly broken at this same point.

It follows from this that the disturbing forces have not, primarily at least, depended upon the density of the disturbing medium as connected with its distance from the sun. We have, therefore, calculated the value of R, the disturbing force in the direction of the radius, positive outwards; S, the disturbing force in the plane of motion perpendicular to R, positive in the direction of the motion; and Z, the disturbing force perpendicular to the plane of motion, positive upwards. It has been necessary to assume that the region in which disturbances occur is situated symmetrically as regards the comet's perihelion, that its limit lay at four-tenths of the earth's mean distance — a nearer limit being forbidden by the disturbance suffered by *Mercury* as shown in our last paper — and also, that the disturbing forces were constant during the transit. These assumptions render the following figures valueless as absolute measures, but should only slightly affect their relative worth. The formulas employed are the well known expressions found in Oppolzer or Watson.

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Plate I.

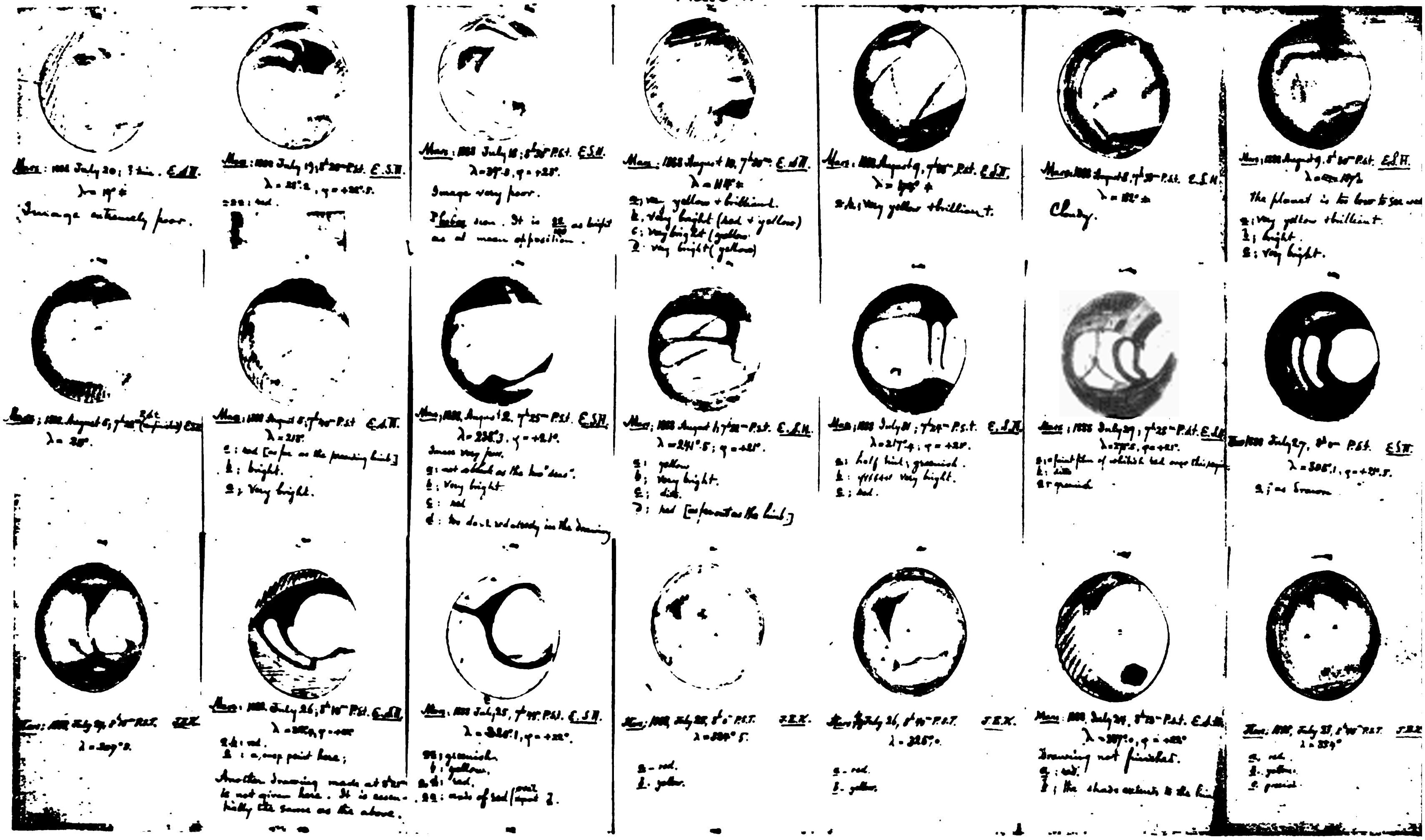
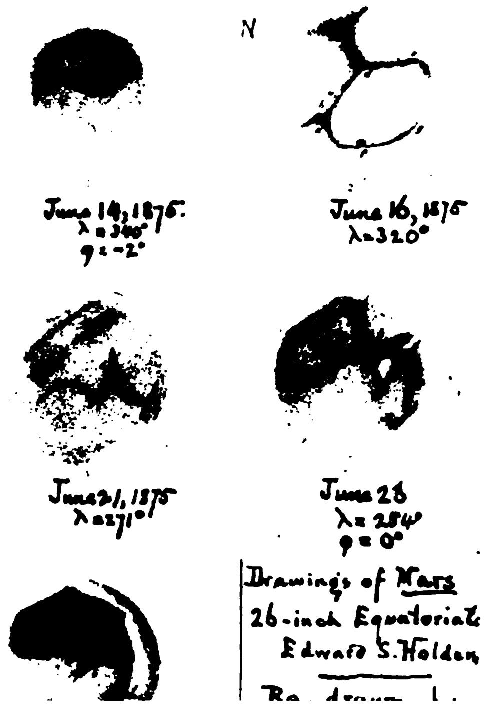


Plate II.



Drawings of Mars
26-inch Equatorial.
Edward S. Holden
Re-drawn ...

Mars: 1877 October 9. W.m.t. $10^h 10^m$. E.S.H.
λ 90° ± φ = 22° ±
The dark spot on the central meridian at $9^h 50^m$ Washington mean time
(Drawing made with the 26-inch Equatorial, power 400. The image is ...

Mars: 1879 November 6. $12^h 54^m$ W.m.t. E.S.H.
$\lambda = 354°$ $\varphi = -13°$
(with 26-inch equatorial.)

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MEAN VALUE FOR THE COMPONENTS OF THE DISTURBING FORCES ACTING UPON ENCKE'S COMET DURING PERIHELION PASSAGE.

Spot No.	S	Z	R
i 90.3	+0.0006542k^2	+0.0011464k^2	—0.0012610k^2
67.2	+0.0001108	+0.0003149	—0.0007686
59.0	+0.0001345	+0.0002786	+0.0003610
54.2	+0.0016774	+0.0048611	—0.0091915
38.3	—0.0010990	+0.0057401	—0.0142970
36.8	—0.0012011	—0.0006302	—0.0057627
20.7	—0.0001882	—0.0003310	—0.0002319
i 3.8	—0.0000272	+0.0003183	+0.0005306
d 3.9	+0.0017287	+0.0060991	—0.0122620
6.0	+0.0000316	—0.0000683	+0.0007396
26.3	—0.0003469	—0.0004951	—0.0004555
27.0	+0.0001218	+0.0003488	+0.0004645
31.4	+0.0001242	+0.0004289	—0.0000462
43.1	+0.0000906	+0.0001322	—0.0015096
50.3	—0.0001791	—0.0002558	—0.0002746
52.7	+0.0000109	+0.0003172	—0.0006933
61.0	—0.0001026	—0.0002338	—0.0016516
93.7	—0.0000872	+0.0000044	—0.0010097
100.0	—0.0002598	—0.0003304	—0.0002245
*d*113.8	—0.0001844	—0.0002492	+0.0008142

The table at the end gives the means formed by uniting those whose sun-spot numbers lie close together.

It is at once apparent that the resultant force has, though variable in the single instance, rapidly increased at the commencement of the sun-spot cycle, reached its maximum near the time of most rapid increase in the number of sun-spots, and then declined, at first rapidly, then irregularly, to the end of the period. It is also evident that the chief disturbance has been towards the sun.

We offer, therefore, the result that the variations in the motion of ENCKE's comet, other than those produced by planetary attraction, are produced by a resisting medium connected with the sun, and disturbed by those forces which produce and are produced by sun-spots. This result will not appear strange when one remembers the conclusion presented by LOCKYER in his *Chemistry of the Sun*, and also the result attained by SHERMAN in a spectroscopic study of certain appearances in the spectrum of β *Lyrae*.

We shall later show that the zodiacal light is intimately connected with these disturbing forces, being in fact a locus of condensation of matter driven from the sun similarly to the tail of a comet from the nucleus, and after condensation again precipitated upon the solar surface.

Spot No.	S	Z	R	Resultant
i 90.3	+0.0006542k^2	+0.0011464k^2	—0.0012610k^2	0.0018255
60.1	+0.0006409	+0.0018184	—0.0031997	0.0037357
31.9	—0.0008294	+0.0015934	—0.0067639	0.0069983
i 2.0	+0.0017331	+0.0021175	—0.0033306	0.0043105
d 31.9	—0.0000336	+0.0000941	—0.0003870	0.0004000
54.7	—0.0000601	—0.0000401	—0.0008732	0.0008761
*d*100.5	—0.0001771	—0.0001916	—0.0001404	0.0002962

EPHEMERIS OF COMET 1888 *c* (*BROOKS*),

BY LEWIS BOSS.

[Continued from No. 178.]

From recent observations of the BROOKS comet it appears probable that it can readily be observed at least up to the October moon. From the same observations I infer that the correction of the ephemeris contained in No. 178 of the Journal will, on Sept. 20, reach about +100^s and —20′ in α and δ, respectively; but as its increase is not very rapid the following will probably answer sufficiently well in the absence of elements based on long intervals.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1888	App. α	App. δ	log Δ	Light
	h m s	° ′		
Sept. 20.5	14 52 35	+22 15.3	0.2317	.45
22.5	15 0 37	+20 46.3	0.2387	
24.5	15 8 17	+19 19.2	0.2460	.39
26.5	15 15 37	17 54.3	0.2536	
28.5	15 22 40	16 31.6	0.2613	.34
30.5	15 29 26	15 11.3	0.2692	
Oct. 2.5	15 35 58	13 53.5	0.2772	.30
4.5	15 42 15	12 38.2	0.2853	
6.5	15 48 17	11 25.5	0.2934	.26
8.5	15 54 8	10 15.4	0.3016	
10.5	15 59 47	9 7.8	0.3098	.22
12.5	16 5 16	8 2.7	0.3180	
14.5	16 10 35	+ 7 0.2	0.3261	.19

Dudley Observatory, 1888 *September* 7.

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OBSERVATIONS AND ORBIT OF COMET 1888 *e* (*BARNARD, Sept.* 2),

[Telegraphically communicated by Prof. E. S. HOLDEN, Director of the Lick Observatory.]

OBSERVATIONS BY PROF. E. E. BARNARD.

Greenwich M.T.	App. α	App. δ
1888 Sept. 3.02344 d	6h 52m 14s.26	+10° 59′ 16″
5.0029	52 6.1	10 51 53
5.9947	51 58.5	+10 47 53

The first of these was in the form of a micrometrical difference from DM. 11°.1377, and has already been given in the last number of the Journal, p. 94. From this the above place was derived by Prof. Boss, who determined the star's place by comparison with WEISSE's *Bessel* 1463.

From observations of Sept. 3, 5 and 7, Prof. J. M. SCHAEBERLE of the Lick Observatory computed the following elements and ephemeris.

ELEMENTS.

T = 1888 Nov. 22.90 Greenwich M.T.
ω = 358° 9′
Ω = 9 3
i = 164 35
q = 1.2749 (log q = 0.10548)

EPHEMERIS FOR GREENWICH NOON.

1888	App. α	App. δ	Light
Sept. 5.0	6h 52m 0s	+10° 52′	1.00
9.0	51 28	10 35	
13.0	50 16	10 16	
17.0	48 28	+ 9 53	1.84

The above elements and ephemeris were cabled to Europe by Mr. RITCHIE on the 10th, and circulated there, as usual, by the *International Science Observer Circular*, and also in a similar circular in this country.

OBSERVATIONS OF COMET 1888 *e* (*BARNARD*),

BY H. V. EGBERT.

Madison M.T.	App. α	App. δ
1888 September 4d 16h 25m 42s	6h 52m 5s.05	+10° 52′ 6″.4
5 16 12 33	51 58.66	10 48 8.3
6 16 11 31	51 51.13	+10 44 3.1

BY W. C. WINLOCK.

[Telegraphed by Superintendent PHYTHIAN of the Naval Observatory.]

Greenwich M.T.	App. α	App. δ
1888 September 12d 20h 57m 7s	6h 50m 36s.6	+10° 18′ 2″

NOTE ON *U GEMINORUM*.

By the elements on p. 86 of this Journal, the next maximum of this variable is due October 15. Its appearances are so sudden (the rise from its ordinary minimum brightness, 13M, to its maximum, about 8M.9 to 9M.7, often occurring in twenty-four hours), and depart so widely from the predicted times, that it is extremely difficult to secure good determinations of the time of maximum. They are, however, important; and it is hoped that observers will keep a nightly watch from the beginning of October.

OCCULTATION OF A STAR (11 MAG.) BY *MARS*.

BY EDWARD S. HOLDEN.

On July 3 the immersion of a small star was observed with the 36-inch refractor, at 9h 1m.0 Pacific standard time. The star was not visible at emersion until it was 5″ from the limb. At 9h 20m the star preceded the limb of *Mars* by exactly one diameter. I assume the star to be an 11 mag. given on CHACORNAC's Chart No. 39 (1852.5), in R.A. 13h 17m 25s ± and Decl. —9° 3′. This star will be observed with the REPSOLD Meridian Circle of the Observatory.

Lick Observatory, 1888 *July* 31.

ANNOUNCEMENT AS TO THE NEW SCIENCE OBSERVER CODE.

[From the *Science Observer Special Circular No.* 82.]

On and after October 1, 1888, the new Science Observer Code will be used in the telegraphic distribution of announcements of discovery.

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FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *c* (*BROOKS*),

MADE AT THE DUDLEY OBSERVATORY,

By LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Aug 26 9 48 17	5	12 , 4	+3 58.51	—4 38.3	12 34 19.54	+40 13 36.1	9.739	0.803
27 8 39 46	6	16 , 8	0 26.79	2 44.3	12 41 7.04	39 41 10.8	9.749	0.703
Sept. 6 8 24 50	7	12 , 4	+5 13.50	—0 47.9	13 45 23.59	+32 50 59.0	9.711	0.694

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
5	12 30 21.82	—.79	+40 18 8.4	+6.0	Weisse 613
6	12 40 40.74	.49	39 43 48.6	6.5	Bonn VI 39°.2559
7	13 40 10.31	—.22	+32 51 39.0	+7.9	Leiden A.G. zones (2)

NOTES. — Aug. 26. Comet extremely faint owing to fog. Aug. 27. Sky remarkably clear. The comet has a star-like nucleus of about eleventh magnitude upon which the observation could be sharply made. The surrounding nebulosity is well condensed and symmetrical — perhaps 25 in diameter. The tail was faintly perceptible in approximate position-angle 310°, and is estimated to be about 3′ in length. The total effect of the light of the head was estimated to be a little fainter than the comparison-star — say magnitude 9.5.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *e* (*BARNARD*),

MADE AT THE DUDLEY OBSERVATORY,

By LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Sept. 5 15 26 14	1	18 , 6	—2 48.22	+1 35.8	6 51 59.37	+10 48 28.6	n9.605	0.729
5 16 29 28	1	9 , 3	—2 48.17	+1 23.6	6 51 59.42	10 48 17.2	n9.528	0.705
6 15 25 58	1	21 , 7	—2 55.94	—2 30.0	6 51 51.67	10 44 22.8	n9.602	0.728
10 15 51 21	2	15 , 5	—1 32.57	+2 28.5	6 51 7.34	10 27 10.5	n9.554	0.714
10 16 18 13	3	9 , 3	—3 53.32	+4 17.7	6 51 7.26	+10 27 3.7	n9.512	0.705

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	6 54 46.97	+.62	+10 46 53.6	—0.8	Glasgow 1720
1		.64		0.8	" "
2	6 52 39.16	.75	10 24 42.7	0.7	Schjellerup 2450
3	6 54 59.85	+.73	+10 22 46.7	—0.7	Schjellerup 2471

NOTES. — Sept. 5. The comet has a soft but condensed light. The coma is somewhat less than 30″ in diameter, and symmetrical. The condensation is very uniform toward the center, without a distinct nucleus. Under illumination the central parts — some 5″ in diameter — appear as a star of the 11.5 magnitude. Sept. 6. There is a very small nucleus of about the 13th magnitude. Sept. 10. The nebulosity is elliptical, with axes of about 40″ and 60″, respectively. The position-angle of the major axis is roughly estimated 315°. Nuclear condensation well marked, and is perhaps 10″ south of the center of the nebulous mass.

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ELEMENTS AND EPHEMERIS OF COMET 1888 *e* (*BARNARD*),

BY LEWIS BOSS.

The elements here presented depend upon the mean of observations at Albany and Madison (Wis.) on Sept. 6.9, the mean of two observations at Albany on Sept. 10.9, and a position formed by applying the micrometer differences obtained by BARNARD at the discovery observation to a position secured at Albany by comparing the comparison-star used by BARNARD with *Weisse* VI 1463, which was observed by SCHJELLERUP also. The Madison positions of Sept. 4, 5 and 6, were kindly communicated by Mr. H. V. EGBERT.

Following are the elements:

$$T = 1888 \text{ December } 10.4074 \text{ G.M.T.}$$

$$\left.\begin{aligned} \omega &= 357^\circ\ 45'.8 \\ \Omega &= 8\ \ 22.7 \\ i &= 165\ \ \ 6.8 \end{aligned}\right\} \text{Apparent equinox}$$

$$\log q = 0.13683$$

The outstanding differences (C—O) for Sept 6.9 were: $\Delta\lambda \cos\beta$, $+42''.0$; $\Delta\beta$, $+4''.4$. The theoretical ratio of these differences should have been $+9.0$, and is actually found to be $+9.5$. Further, the quotient of tan $(\lambda - L)$ by sin β, for the middle place (expressed as a logarithm) was for the observed λ and β, 9.385839, and for the calculated λ and β, 9.385842. It therefore appears that no essentially better representation of the middle place could have been obtained through a value of the ratio of geocentric distances differing very much from that actually employed. The large discrepancy in longitude points either to an error in the data employed; or it is barely possible that it may be due to variation from parabolic motion.

It goes without saying that the determination of elements under the circumstances, in which the total motion in geocentric longitude for eight days was less than 14′, and in latitude less than 34′, is extremely uncertain. I therefore offer the subjoined ephemeris, not with the expectation that the comet will actually follow the indicated path very closely. It may be mentioned that the present elements give a theoretical brightness at perhelion of about 70, which would be largely increased by the known tendency of comets to exceed their theoretical brightness when moving toward perihelion.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1888	App. α	App. δ	log Δ	Light
	h m s	° ′		
Sept. 12.5	6 50 39	+10 19	0.2978	1.44
16.5	6 49 4	9 59	0.2694	1.70
20.5	6 46 40	9 35	0.2384	2.04
24.5	6 43 25	9 7	0.2055	2.47
28.5	6 39 9	8 36	0.1672	3.07
Oct. 2.5	6 33 15	7 58	0.1262	3.85
6.5	6 25 22	+ 7 12	0.0810	4.93

Dudley Observatory, 1888 *September* 11.

ON THE NEW VARIABLE *V HYDRAE*,

$10^h\ 44^m\ 34^s$; $-20^\circ\ 28'.8$ (1855.0),

BY E. F. SAWYER.

This star, which is No. 3881 of CHANDLER's Catalogue, lies within the region of my revision of the *Uranometria Argentina*; and, upon seeing the announcement by Mr. CHANDLER of his establishment of its variability, I have gone over my records for this work, and also of observations of suspected variables. I find one observation of it on 1884 March 22, at about 9^h. The star was then 5 steps brighter than SDM. —20°.3280, and 3 steps fainter than SDM. —19°.3122; thus about $7^M.4$. This year the star has not been much brighter than 9^M, being barely visible in the field-glass. Hence the variability appears to be fully confirmed.

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THE

ASTRONOMICAL JOURNAL.

No. 182.

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ON THE MUTUAL ACTION OF THE SATELLITES OF *SATURN*,

BY SIMON NEWCOMB.

Four years ago I showed that the apocentre of *Hyperion* moves under a law unrecognized in the case of any other body of the solar system, in that it librates on each side of the mean conjunction-point of *Hyperion* and *Titan*. The theory of the motion has been discussed by TISSERAND, STONE, and HILL. The last two have, by mechanical quadrature, derived a mass of *Titan* which is probably very accurate.* TISSERAND has shown that the motion of the pericentre of *Hyperion* may be represented as a perturbation of the coordinates of the satellite, and STONE has considered the subject from this point of view.

I now propose to consider the question whether similar relations may not subsist among the motions of the five inner satellites, and to indicate the general theory on which such relations depend.

§1. The apprehension of the theory is facilitated by the conception of conjunction-points. Let l and l' be the common mean longitudes of two planets or satellites at two consecutive mean conjunctions. If we assign to an imaginary point such a constant mean motion that it moves from l to l' during the interval between two consecutive mean conjunctions, then all mean conjunctions of the actual bodies will take place on this moving point. Instead of a single conjunction-point, we may choose several equidistant ones, affected with a common movement such that the actual conjunctions shall take place on the several points in some consecutive order. The theory of the subject, which is quite simple, is developed in *Astronomical Papers of the American Ephemeris*, Vol. I.

If the mean motions n and n' of two bodies are such that (i being any integer), $(i+1)n'-in$ is small compared with n or n', the motion of the conjunction-point will be slow compared to n or n'.

We then have the following theorems:—

I. If, in the case of two nearly circular orbits, the motion of the conjunction-point, taken singly, is slow compared with that of the bodies, then the mutual action of the latter will tend to generate an eccentricity in each orbit, such that the lines of apsides of the orbits shall coincide with the conjunction-point.

II. At any epoch such values may be assigned to the eccentricities and pericentres of the two orbits, that the eccentricities shall remain invariable, while the line of apsides shall move round with the conjunction-point.

III. If the eccentricity and pericentre differ a little from the values thus defined, they will librate around those values.

To derive these theorems we have to consider only the terms of the disturbing force which are of the lowest order with respect to the eccentricities, together with those arising from the ellipticity of the planet. These terms are:—

For the action of the outer on the inner body:

$$R = \tfrac{1}{2}\beta\frac{\mu}{a}e^2 + \frac{m'}{a'}e\gamma\cos\Big((i+1)\,l'+il-\pi\Big)$$

and for the action of the inner on the outer one,

$$R' = \tfrac{1}{2}\beta\frac{\mu}{a'}e'^2 + \frac{m}{a'}e'\gamma'\cos\Big((i+1)\,l'+il-\pi'\Big)$$

Here β is a numerical factor, depending on the ellipticity of the central body, μ is the mass of the latter, and γ and γ' are functions of the mean distances. The other symbols have the usual signification.

Instead of e and π we introduce rectangular coordinates of the centre of the orbit, taken negatively,

$$h = e\sin\pi \qquad h' = e'\sin\pi'$$
$$k = e\cos\pi \qquad k' = e'\cos\pi'$$

Then the known differential equations for h and k are,

$$D_t h = \frac{an}{\mu}\frac{dR}{dk}, \qquad D_t h' = \frac{a'n'}{\mu}\frac{dR'}{dk'}$$

$$D_t k = -\frac{an}{\mu}\frac{dR}{dh}, \qquad D_t k' = -\frac{a'n'}{\mu}\frac{dR'}{dh'}$$

Putting for brevity

$$V = (i+1)l' - il$$

* The agreement between the values of the mass deduced independently, by HILL, from the motion of *Hyperion*, and by H. STRUVE, from that of *Iapetus*, is remarkable. HILL's value is $\frac{1}{4714}$, STRUVE's $\frac{1}{4678}$ (Cf. this Journal, No. 176).

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the longitude of the conjunction-point,

$$\nu = \frac{n}{(i+1)\, n'+in}$$

$$\nu' = \frac{n'}{(i+1)\, n'+in}$$

$$\alpha = \frac{a}{a'}$$

we shall have

$$R = \tfrac{1}{2}\frac{\beta\mu}{a}\,(h^2+k^2) + \frac{m'\gamma}{a'}\,(h \sin V + k \cos V)$$

$$R' = \tfrac{1}{2}\frac{\beta'\mu}{a'}\,(h'^2+k'^2) + \frac{m\gamma'}{a'}\,(h' \sin V + k' \cos V)$$

$$D_t h = \beta n k + \frac{m'\alpha n}{\mu}\,\gamma \cos V$$

$$D_t k = -\beta n h - \frac{m'\alpha n}{\mu}\,\gamma \sin V$$

$$D_t h' = \beta' n' k' + \frac{m n'}{\mu}\,\gamma' \cos V$$

$$D_t k' = -\beta' n' h' - \frac{m n'}{\mu}\,\gamma' \sin V$$

The integrals of these equations may be put into the form

$$h = \frac{m'\alpha\nu\gamma}{\mu(1-\beta\nu)} \sin V + c \sin(\varepsilon+\beta n t)$$

$$k = \frac{m'\alpha\nu\gamma}{\mu(1-\beta\nu)} \cos V + c \cos(\varepsilon+\beta n t)$$

$$h' = \frac{m\nu'\gamma'}{\mu(1-\beta'\nu')} \sin V + c' \sin(\varepsilon'+\beta' n' t)$$

$$k' = \frac{m\nu'\gamma'}{\mu(1-\beta'\nu')} \cos V + c' \cos(\varepsilon'+\beta' n' t)$$

c, c', ε and ε' being arbitrary constants. If these constants vanish these values of h and k will give

$$e = \pm \frac{m'\alpha\nu\gamma}{\mu(1-\beta\nu)}$$

$$\pi = V \text{ or } V \pm 180^\circ$$

It will be remarked that the product $\beta\nu$ is the ratio of the secular motion of the perihelion, arising from the ellipticity of the planet, to the motion of the conjunction-point. It follows that, if these motions are nearly equal, the eccentricity will be greatly increased, and that if the former is the greater, the direction of the perihelion of the disturbed planet will be reversed.

§ 2. The pairs of satellites to which the preceding theory best applies, are *Mimas-Tethys* and *Enceladus-Dione*. The following are the values of the mean daily motions.

Mimas; $n =$	$381^\circ.9908$	*Enceladus;* $n =$	$262^\circ.7318$
Tethys; $2n' =$	381.3968	*Dione;* $2n' =$	263.0698
$D_t V =$	-0.5940	$D_t V =$	$+0.3380$

Admitting that the annual motion of the pericentre due to the ellipticity of *Saturn* is 31′.3 in the case of *Titan*, we have the following daily motions of the pericentres of the satellites in question due to this cause. The estimated masses are added.

	$D_t \pi$	$\frac{m}{\mu}$
Mimas	$+1^\circ.050$	1 : 500 000
Enceladus	0.438	1 : 270 000
Tethys	0.207	1 : 75 000
Dione	+0.087	1 : 85 000

The masses are estimated from Pickering's photometric comparisons, assuming the density and albedo of each to correspond to those of *Titan*, and the mass of the latter to be 1 : 4800. Of course such estimates are hardly better than rough guesses.

An inspection of the preceding constants shows that the largest eccentricity generated by the action will be that of *Enceladus* due to the action of *Dione*. In the case of the action of the latter planet on the former we have for the term of the perturbative function which comes into play: —

$$\frac{a}{a'} = 0.6305$$

$$\begin{aligned} a'R &= -1.193\, em' \cos(2l'-l-\pi) \\ &= -1.193\, m'(h \sin V + k \cos V) \\ D_t h &= .00167\, nk - .000\,008\,95\, n \cos V \\ D_t k &= -.00167\, nh + .000\,008\,95\, n \sin V \end{aligned}$$

The integration of these equations gives

$$\begin{aligned} h &= e \sin \pi = .024 \sin V + c \sin(0^\circ.438t+\varepsilon) \\ k &= e \cos \pi = .024 \cos V + c \cos(0^\circ.438t+\varepsilon) \end{aligned}$$

If we substitute for V its value given by observations, reduce the time t from days to years, and put for ω the distance of the pericentre from the node of the ring upon the equator, we shall have

$$\begin{aligned} e \sin \omega &= .024 \sin(V_0+123^\circ.5t) + c \sin(\varepsilon+160^\circ.0t) \\ e \cos \omega &= .024 \cos(V_0+123^\circ.5t) + c \cos(\varepsilon+160^\circ.0t) \end{aligned}$$

Here V_0 is the longitude of the conjunction-point at the epoch $t = 0$ counted from the same origin as ω. The arbitrary constants c and ε can be determined only from observation.

Owing to the fact that the motions of the two angles differ by only 36° per annum, the eccentricity may have a 10-year period, and the two terms can be completely separated only by observations extending through that period. In the discussion of the observations it is to be noted that three unknown quantities enter into the expression, namely, c, ε and the correction of the coefficient .024. This contains the mass of *Tethys* as a factor, and therefore depends on the value of that mass.

There are a number of other relations of long period among the satellites of *Saturn*. But from an examination of them all I infer that none, except those already considered, can give rise to inequalities large enough to be detected by observations from the earth.

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THE AUGUST *PERSEIDS*, 1888,

BY EDWIN F. SAWYER.

The observations of this annual meteor shower were confined this year to the evening of August 10, all the other evenings from August 6 to 13, inclusive, being unfortunately overcast. The night of the 10th, however, was remarkably clear, and a watch of three hours was maintained, beginning at ten o'clock. The observations were made at Beachmont, Mass., and the center of observation was in *Perseus*. I was ably assisted by Mr. CHARLES W. MEAD, who kept a record of the number of meteors seen in each half hour, their magnitudes, etc.; while my attention was confined to mapping such tracks as were observed with sufficient accuracy to be of use in determining radiant points. The following table shows the number of meteors recorded by Mr. MEAD during the watch of three hours.

Limits of Watch	Duration	Meteors Seen		
		Perseids	Others	Total
10h 0m – 10h 30m	30m	13	7	20
10 30 – 11 0	30	17	4	21
11 0 – 11 30	30	18	7	25
11 30 – 12 0	30	27	11	38
12 0 – 12 30	30	21	5	26
12 30 – 15 0	30	22	10	32
Total	180	118	44	162

Per cent. of *Perseids*, 73.0; of other meteors, 27.0. The magnitudes of those recorded were as follows:

	>1ᴹ	1ᴹ	2ᴹ	3ᴹ	4ᴹ<	Total
Perseids	5	15	29	17	52	118
Others	0	3	4	6	31	44
Total	5	18	33	23	83	162

Thirty-three tracks were mapped, twenty of them having been very accurately noted. The radiant-point of the *Perseids* was very precisely fixed at, R.A. 47°.5; Decl. +58°.

Cambridgeport, 1888 *September* 16.

METEOR TRACKS MAPPED.

No.	Camb. M.T.	Mag.	Observed Path				Length of Path	Wt.
			From		To			
			R.A.	Decl.	R.A.	Decl.		
1	9h 7m	3	44°	+61°	35°	+62°	5	4
2	9 24	>1	7	29	358	16	14	4
3	9 53	2	256	29½	347	12	16	2
4	9 58	4	7	53½	352	53½	10	3
5	10 0	1	165	75	184	57	16	4
6	10 4	3	20	59½	10	59	4	4
7	10 12	3	10	30	4	11	18	3
8	10 17	1	26	27	22	15	13	3
9	10 20	5	29	42	31½	31	11	4
10	10 23	3	22	62	10	61½	6	4
11	10 26	4	11	60	359½	58½	6	4
12	10 28	1	17	36	30	35	10	2
13	10 43	>1	49	59	39	55	6	4
14	10 44	3	30	42	32	31	11	4
15	10 45	3	20	64	358	65	10	3
16	10 49	1	65	53	72½	49	7	3
17	10 56	1	43½	39	43	29	10	4
18	10 57	2	355	89½	226	75	12	4
19	11 13	5	15	55	8	53	6	4
20	11 25	1	33	33	31	22	12	4
21	11 30	5	28½	40	26	29	11	4
22	11 40	3	54	41	56	33	8	3
23	11 41	5	350	56	356	57½	4	4
24	11 44	1	359	27½	343½	15	15	3
25	11 46	1	10	30	20	15	15	3
26	11 55	1	29	42	31	31	10	4
27	12 0		7	39½	356½	28½	11	4
28	12 14	1	355	88½	234	71	16	4
29	12 30	4	358	56½	7	58	6	4
30	12 35	1	46	54	60	58½	9	3
31	12 38	2	25	72	5	87	15	3
32	12 40	2	53	30	55	20	10	3
33	12 42	2	7	+53	355	+48½	8	4

NOTES. — Nos. 3, 14 and 18 were mapped by Mr. MEAD. Nos. 17, 27 and 30 were of a green color. No. 27 was a very fine one, as bright as *Jupiter*, and left a streak visible fifteen seconds. In the column of weights, 4 indicates an accurate observation, 1 a poor one.

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1888.

[For remarks and comparison-stars see Vol. VII, p. 187 ff.]

October	d h	October	d h	October	d h	October	d h	October	d h
R Canis Maj.	15 19	*U* Cephei	20 15	*U* Coron. Bor.	23 12	λ Tauri	25 18	Algol	30 8
U Coron. Bor.	16 15	*R* Canis Maj.	21 11	*R* Canis Maj.	23 17	Algol	27 11	*U* Coron. Bor.	30 10
Y Cygni	16 16	Algol	21 17	Algol	24 14	*Y* Cygni	28 15	*R* Canis Maj.	30 13
λ Tauri	17 20	λ Tauri	21 19	*R* Canis Maj.	24 21	*R* Canis Maj.	29 10	*U* Cephei	30 14
Algol	18 20	*R* Canis Maj.	22 14	*U* Cephei	25 15	*S* Cancri	29 12	*Y* Cygni	31 15
Y Cygni	19 16	*Y* Cygni	22 15	*Y* Cygni	25 15	λ Tauri	29 17	*R* Canis Maj.	31 16

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November	d	h	November	d	h	November	d	h	December	d	h	December	d	h
λ Tauri	2	16	Algol	16	13	*Y* Cygni	27	14	*Y* Cygni	6	14	*R* Canis Maj.	20	16
R Canis Maj.	2	23	*R* Canis Maj.	16	14	*U* Cephei	29	12	λ Tauri	8	6	*Y* Cygni	21	13
Y Cygni	3	15	*S* Cancri	17	11	λ Tauri	30	8	*R* Canis Maj.	9	7	*R* Canis Maj.	21	19
U Cephei	4	14	*R* Canis Maj.	17	17	*Y* Cygni	30	14	Algol	9	11	*R* Canis Maj.	22	23
λ Tauri	6	15	λ Tauri	18	11	Algol	30	20	*U* Cephei	9	12	Algol	23	19
Y Cygni	6	15	*Y* Cygni	18	15				*Y* Cygni	9	14	*U* Cephei	24	11
R Canis Maj.	8	15	*R* Canis Maj.	18	20	December			*R* Canis Maj.	10	11	*Y* Cygni	24	13
U Cephei	9	14	Algol	19	9	*R* Canis Maj.	1	9	*R* Canis Maj.	11	14	*S* Cancri	25	9
Y Cygni	9	15	*U* Cephei	19	13	*R* Canis Maj.	2	12	Algol	12	8	*R* Canis Maj.	26	8
R Canis Maj.	9	18	*Y* Cygni	21	14	*Y* Cygni	3	14	*Y* Cygni	12	14	Algol	26	16
λ Tauri	10	15	Algol	22	6	*R* Canis Maj.	3	15	*R* Canis Maj.	12	17	*R* Canis Maj.	27	12
Algol	10	19	λ Tauri	22	10	Algol	3	17	*R* Canis Maj.	13	21	*Y* Cygni	27	13
Y Cygni	12	15	*U* Cephei	24	13	λ Tauri	4	7	*U* Cephei	14	11	*R* Canis Maj.	28	15
Algol	13	16	*R* Canis Maj.	24	13	*U* Cephei	4	12	*Y* Cygni	15	14	*U* Cephei	29	10
λ Tauri	14	12	*Y* Cygni	24	14	*R* Canis Maj.	4	18	*R* Canis Maj.	18	10	Algol	29	13
U Cephei	14	13	*R* Canis Maj.	25	16	*R* Canis Maj.	5	22	*Y* Cygni	18	14	*R* Canis Maj.	29	18
R Canis Maj.	15	11	λ Tauri	26	9	*S* Cancri	6	10	*U* Cephei	19	11	*Y* Cygni	30	13
Y Cygni	15	15	*R* Canis Maj.	26	19	Algol	6	14	*R* Canis Maj.	19	13	*R* Canis Maj.	30	21

ON THE VALUE OF THE SOLAR PARALLAX DEDUCIBLE FROM THE AMERICAN PHOTOGRAPHS OF THE LAST TRANSIT OF *VENUS*,

By WILLIAM HARKNESS.

[Abstract of a paper read at the Meeting of the American Association for the Advancement of Science, at Cleveland, O., August, 1888.]

In this paper an account was given of the instruments and processes employed by the U.S. Transit of *Venus* Commission in determining the solar parallax from photographs of the transit of *Venus* which occurred in December, 1882. Let π be the solar parallax, and δA and δD, respectively, the corrections to the right ascensions and declinations of *Venus* given by Hill's tables of that planet. Then, upon the assumption that Hansen's tables of the sun are correct, there resulted from measurements of the distances between the centers of the sun and *Venus*, made upon 1475 photographs taken, respectively, at Washington, D.C.; Cedar Keys, Fla.; San Antonio, Tex.; Cerro Roblero, N.M.; Wellington, South Africa; Santa Cruz, Patagonia; Santiago, Chili; Auckland, New Zealand; Princeton, N.J.; and the Lick Observatory, Cal.,

$$\pi = 8.847'' \pm 0.012''$$
$$\delta A = +2.893$$
$$\delta D = +1.254$$

and the corresponding mean distance from the earth to the sun is 92,385,000 miles, with a probable error of only 125,000 miles.

These numbers are doubtless close approximations to the results which will be obtained from the complete discussion of all the photographs, but they cannot be regarded as final, for several reasons, chief among which is the fact that the reduction of the position angles of *Venus* relatively to the sun's center is still unfinished. When these angles are combined with the distances, it is likely that the probable error of the parallax will be somewhat reduced.

The photographs taken at the Lick Observatory seem to indicate that for altitudes four thousand feet above the sea level the values of the refraction given by the tables in general use are somewhat too large.

Washington, D.C., 1888 *September* 14.

DISCOVERY AND OBSERVATIONS OF A COMET, 1888 *e*,

By E. E. BARNARD, Astronomer of the Lick Observatory.

[Communicated by the Director.]

On the morning of September 3, after observing Faye's comet, I began comet seeking with the 4-inch broken-tube comet seeker. A faintish and suspicious object being swept up, it was at once examined with the 12-inch equatorial, and from its physical appearance and the absence of any recorded nebula at its place, it was assumed to be a comet, and filar-micrometer positions were obtained. No certain motion could be detected during these observations; but, from a thorough knowledge of that region of the sky, I had no hesitation in announcing it as a comet.

The comet was round, about 1′ in diameter, gradually brighter in the middle to an ill-defined nucleus, with no

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trace of tail. It was estimated to be about the eleventh magnitude.

The following are the observations so far obtained. These observations have been corrected for differential refraction.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *e*,

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1888. Mt. Hamilton M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Red. to app. place α	Red. to app. place δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″	s	″
Sept. 2 16 22 37	1	7, 6	+0 58.11	— 7 58.1	6 52 14.20	+10 59 17.9	n9.589	0.648	+0.56	—1.0
3 16 2 20	2	8, 6	—1 17.64	— 7 11.1	6 52 10.16	10 55 45.1	n9.617	0.661	0.57	0.9
4 15 3 1	2	6, 3	—1 22.76	—10 54.9	6 52 5.03	10 52 1.4	n9.659	0.686	0.59	0.8
4 15 57 38	3	16, 4	—2 42.68	+ 4 55.0	6 52 5.24	10 51 48.4	n9.613	0.658	0.60	0.8
5 15 46 2	3	12, 3	—2 49.14	+ 0 58.8	6 51 58.81	10 47 52.2	n9.619	0.661	0.62	0.8
6 15 46 56	3	10, 3	—2 57.00	— 3 6.1	6 51 50.95	10 43 47.3	n9.613	0.659	0.63	0.8
7 15 56 8	4	20, 9	—0 10.80	+ 1 27.0	6 51 41.85	10 39 34.4	n9.599	0.657	0.67	0.6
8 15 58 44	4	14, 5	—0 21.41	— 2 48.6	6 51 31.26	10 35 18.8	n9.589	0.653	0.69	0.6
12 15 43 48	5	7, 5	+0 17.32	+11 21.8	6 50 34.34	10 17 25.0	n9.589	0.653	0.83	0.6
14 15 57 19	5	20, 3	—0 21.28	+ 1 49.4	6 49 55.79	10 7 52.6	n9.551	0.646	0.88	0.6
16 15 34 9	5	8, 5	—1 6.56	— 8 3.0	6 49 10.56	9 58 0.3	n9.574	0.653	0.94	0.5
17 16 20 11	6	12, 6	—0 19.58	+ 5 14.8	6 48 44.09	9 52 41.4	n9.480	0.634	0.97	0.4
17 16 45 41	5	4, 3	—1 33.43	—13 23.2	6 48 43.72	9 52 40.2	n9.408	0.626	0.97	0.5
18 16 24 16	6	8, 1	—0 47.46	± 0 0.0	6 48 16.24	+ 9 47 26.7	n9.458	0.631	+0.98	—0.3

Mean Places for 1888.0 of Comparison-Stars.

*	α	δ	Authority
	h m s	° ′ ″	
1	6 51 15.53	+11 7 17.0	Comp. with Schj. 2431
2	6 53 27.23	11 2 57.1	Comp. with star 1
3	6 54 47.32	10 46 54.2	½(2 Arm₂ 844 + W.B. VI, 1628)
4	6 51 51.98	10 38 8.0	W.B. VI, 1535
5	6 50 16.19	10 6 3.8	B.B. VI, 10°,1335
6	6 49 2.71	9 47 27.0	W.B. VI, 1437

ELEMENTS OF COMET 1888 *e*,

BY W. C. WINLOCK.

[Communicated by the Superintendent U S. Naval Observatory.]

The following elements were computed from the mean of the Albany, Madison and Lick observations of Sept. 5, and Washington observations of Sept. 12 and 19; the position of the 19th being:

Sept. 19, $15^h\,50^m\,47^s$, $\alpha = 6^h\,47^m\,50^s.94$, $\delta = +9°\,42'\,54''.2$

$$T = 1889 \text{ Jan. } 31.01675 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 340°\,40'\,46'' \\ \Omega &= 357\ \ 30\ \ 57 \\ i &= 166\ \ 21\ \ 57 \end{aligned}\right\} 1888.0$$

$$\log q = 0.257942$$

A comparison with the Albany observation of Sept. 10, and the middle place, Sept. 12, gives:

		Sept. 10	Sept. 12
(O—C)	$\Delta\lambda \cos\beta =$	$-3''.9$	$+2''.4$
	$\Delta\beta =$	-0.9	$+0.9$

Washington, 1888 *September* 24.

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ELEMENTS AND EPHEMERIS OF COMET 1888 *e*,

BY LEWIS BOSS.

The elements herein given are computed from observed positions of the BARNARD comet, which approximate the dates September 5.9, September 14.9 and September 26.8. The first is formed from the mean of two Albany places combined with a Mt. Hamilton and another Madison position; for the remaining dates the position was determined at Albany. Assistance was derived from a list of positions kindly communicated by Mr. BARNARD. From four of these a normal place was formed of date September 18.001.

The elements derived are these:

$$
\begin{aligned}
T &= \text{1889 January 31.2269 G.M.T.}\\
\omega &= 340^\circ\ 30'\ 29''\\
\Omega &= 357\ \ 25\ \ 53\\
i &= 166\ \ 22\ \ 10\\
\log q &= 0.258795
\end{aligned}
$$

The residual differences for the Albany observation of Sept. 14.9 are: $\Delta\lambda = -0''.8$; $\Delta\beta\ +1''.1$; and for the Mt. Hamilton mean position of Sept. 18.0010: $\Delta\lambda = -4''.9$; $\Delta\beta = +3''.6$.

From these elements it appears that the geocentric distance will be greater than unity throughout, and the maximum brightness (Nov. 21) will be only twelve times that of discovery, or perhaps 8.5 magnitude. It appears that the comet will remain visible until about March 1, when its distance from the sun is about 25° and its brightness twice that of discovery.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1888	App. α	App. δ	log r	log Δ	Light
	h m s	° ′			
Sept. 30.5	6 40 3	+8 38.0	0.37505	0.3393	1.9
Oct. 1.5	6 39 2	8 31.0	0.37364	0.3334	
2.5	6 37 58	8 23.9	0.37223	0.3274	
3.5	6 36 50	8 16.5	0.37083	0.3214	
4.5	6 35 38	8 9.0	0.36943	0.3152	2.1
5.5	6 34 23	8 1.3	0.36803	0.3090	
6.5	6 33 3	7 53.3	0.36664	0.3027	
7.5	6 31 39	7 45.2	0.36525	0.2964	
8.5	6 30 11	7 36.8	0.36386	0.2899	2.5
9.5	6 28 38	7 28.2	0.36247	0.2834	
10.5	6 27 1	+7 19.4	0.36108	0.2768	
Oct. 11.5	6 25 18	+7 10.3	0.35969	0.2701	
12.5	6 23 30	7 1.0	0.35830	0.2634	2.9
13.5	6 21 37	6 51.4	0.35692	0.2565	
14.5	6 19 39	6 41.6	0.35554	0.2497	
15.5	6 17 34	6 31.5	0.35416	0.2427	
16.5	6 15 24	6 21.0	0.35278	0.2357	3.3
17.5	6 13 7	6 10.2	0.35140	0.2286	
18.5	6 10 44	5 59.1	0.35002	0.2215	
19.5	6 8 14	5 47.7	0.34865	0.2143	
20.5	6 5 37	5 35.9	0.34728	0.2071	3.9
21.5	6 2 53	5 23.9	0.34592	0.1998	
22.5	6 0 1	5 11.5	0.34456	0.1924	
23.5	5 57 1	4 58.7	0.34320	0.1850	
24.5	5 53 52	4 45.5	0.34184	0.1777	4.6
25.5	5 50 36	4 31.8	0.34148	0.1704	
26.5	5 47 11	4 17.8	0.34013	0.1631	
27.5	5 43 37	4 3.3	0.33879	0.1559	
28.5	5 39 54	3 48.3	0.33645	0.1487	5.4
29.5	5 36 2	3 32.8	0.33512	0.1415	
30.5	5 31 58	3 16.8	0.33379	0.1344	
31.5	5 27 45	3 0.4	0.33246	0.1273	
Nov. 1.5	5 23 22	2 43.6	0.33114	0.1202	6.3
2.5	5 18 49	2 26.4	0.32982	0.1132	
3.5	5 14 6	2 8.7	0.32851	0.1064	
4.5	5 9 12	1 50.7	0.32720	0.0999	
5.5	5 4 7	1 32.2	0.32590	0.0936	7.3
6.5	4 58 52	1 13.3	0.32461	0.0874	
7.5	4 53 26	0 54.1	0.32332	0.0814	
8.5	4 47 50	0 34.5	0.32204	0.0757	
9.5	4 42 4	+0 14.6	0.32076	0.0703	8.3
10.5	4 36 9	—0 5.6	0.31949	0.0652	
11.5	4 30 4	0 26.1	0.31823	0.0604	
12.5	4 23 49	0 46.6	0.31698	0.0600	
13.5	4 17 27	1 7.2	0.31574	0.0519	9.3
14.5	4 11 57	1 27.9	0.31450	0.0453	
15.5	4 4 20	1 48.6	0.31327	0.0450	
16.5	3 57 37	2 9.2	0.31204	0.0424	
17.5	3 50 48	—2 29.5	0.31081	0.0399	10.0

Dudley Observatory, 1888 *September* 29.

ADDITIONAL OBSERVATIONS OF COMET 1888 *e*,

BY E. E. BARNARD.

[Telegraphically communicated by Prof. E. S. HOLDEN, Director of the Lick Observatory.]

Greenwich M.T.	App. α	App. δ
d	h m s	° ′ ″
1888 Sept. 26.0217	6 43 57.8	+9 7 14
27.0296	43 10.6	9 1 1
28.0286	42 20.2	8 54 33
29.0204	41 28.0	+8 48 1

The above observations are all we have to send at present, in addition to those already communicated by mail.

San José, Cal., 1888 *Sept.* 29.

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FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *e*,

MADE AT THE DUDLEY OBSERVATORY,

BY LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Sept. 13 14 35 23	5	7,7	+0 2.96	+7 36.2	6 50 19.97	+10 13 39.2	*n*9.618	0.738
13 15 2 34	4	15,5	+2 6.57	+2 24.0	6 50 19.25	10 13 31.9	*n*9.596	0.728
14 15 50 53	5	36,18	—0 18.52	+2 30.4	6 49 58.52	10 8 33.4	*n*9.529	0.710
24 15 28 39	6	15,5	+4 23.07	—4 54.7	6 44 48.77	9 14 21.3	*n*9.489	0.711
26 14 29 21	7	18,6	—6 21.51	+1 13.5	6 43 20.96	+ 9 2 24.1	*n*9.567	0.727

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
4	6 48 11.80	+0.88	+10 11 8.5	—0.6	Weisse's Bessel 1414
5	6 50 16.15	0.86	10 6 3.6	0.6	Bonn VI, 10°1335
5		0.89		0.6	
6	6 40 24.50	1.20	9 19 16.0	0.0	Comp. with Bonn VI, 9°1383
7	6 49 41.25	+1.22	+ 9 1 10.9	—0.3	Bonn VI, 9°1442 (2 obs.)

NOTES.

Sept. 13. * The comet appears to be somewhat indefinitely elongated in position angle 352°.

Sept. 14. A light fog obscures the coma, but the measures are sufficiently easy. Probable errors: $\Delta\alpha$ ±ˢ.03; $\Delta\delta$ ±0″.2.

Sept. 24. Observation easy in spite of bright moonlight. Lal. 13017 gives 6ʰ 40ᵐ 24ˢ.85, +9° 19′ 24″.1, for the position of the star.

Sept. 26. Moon 21° distant, and comet faint.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *e*,

MADE AT THE WASHBURN OBSERVATORY, MADISON, WIS.,

BY H. V. EGBERT,

[Communicated by permission of the Director.]

1888 Madison M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Sept. 4 16 25 42	1	2, 3	—2 42.52	+ 5 13.8	6 52 5.05	+10 52 6.6	*n*9.534	0.710
5 16 12 33	1	3, 5	—2 48.95	+ 1 15.5	6 51 58.65	10 48 08.3	*n*9.518	0.707
6 16 11 31	1	3, 6	—2 56.49	— 2 49.6	6 51 51.14	10 44 03.2	*n*9.524	0.708
8 16 32 42	2	5, 6	—0 20.62	— 2 33.0	6 54 31.99	10 35 34.0	*n*9.564	0.719
12 16 3 32	3	7, 6	+0 18.29	+11 43.4	6 50 35.23	+10 17 45.7	*n*9.546	0.717

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	6 54 46.97	+.60, +.63, +.66	+10 46 53.6	—0.8	Grant 1720
2	6 51 51.98	+.70	10 38 7.7	0.7	W.B. 1535
3	6 50 16.11	+.83	+10 6 2.9	—0.6	3542 Etoiles Poulkova, 1134

A comparison in R.A. consists of a transit over five threads. The observations have been corrected for differential refraction.

On Sept. 12 the comet was compared with a 9ᴹ.5 star, and this compared with the comparison-star.

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OBSERVATIONS OF COMET 1888 a,

MADE AT THE HAVERFORD OBSERVATORY WITH THE 10-INCH EQUATORIAL,

BY F. P. LEAVENWORTH.

1888 Haverford M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
June 1 15 25 46	1	2	+4 23.78	—4 35.2	0 27 48.97	+40 8 44.2	n9.723	0.371
18 14 51 18	2	6 , 2	—0 13.38	+1 3.1	0 50 29.48	45 1 8.2	n9.751	0.239
18 14 57 8	3	5 , 3	—1 26.81	+1 52.9	0 50 30.18	+45 1 15.5	n9.747	0.219

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	0 23 25.18	+0.01	+40 13 31.6	—12.2	Weisse's Bessel 546
2	0 50 42.42	0.44	45 0 17.2	12.1	Weisse's Bessel 1255
3	0 51 56.54	+0.45	+44 59 34.6	—12.0	Weisse's Bessel 1283

The observation of June 1 was made with a square-bar micrometer. There were three tails seen — a long central one, and a short faint one on each side. The observation of June 18 was made with a filar-micrometer. Nucleus estimated to be of the eleventh magnitude. On both nights the nucleus was barely distinguishable from the tail.

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THE

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OBSERVATIONS OF COMETS,

MADE AT THE DUDLEY OBSERVATORY,

BY LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
1880			☄e 1880 (SWIFT-TEMPEL. Periodic).					
			m s	′ ″	h m s	° ′ ″	s	″
Oct. 11 12 5 43	1	10 , 5	+2 56.77	−1 0.5	21 33 10.97	+17 58 12.7	9.601	0.667
25 9 38 22	2	4		−1 20.9		28 33 12.8		0.414
25 10 4 26	2	10	+2 1.97		21 50 20.13		9.487	
25 10 40 18	2	2		+0 52.3		28 35 26.0		0.495
28 8 24 36	3	10 , 4	+1 16.61	+1 53.0	21 58 14.04	31 23 48.3	9.090	0.257
Nov. 2 10 23 11	4	10 , 4	−0 18.84	+0 23.2	22 17 24.95	36 47 35.2	9.578	0.296
8 10 43 50	5	12 , 4	+2 33.83	+3 36.5	22 52 0.42	43 44 22.6	9.641	0.085
21 7 6 59	6	21 , 7	−2 41.45	−1 23.2	1 18 46.53	54 38 35.7	n9.594	n0.032
25 6 55 41	7	16 , 8	−0 49.46	−1 26.9	2 16 9.82	+54 41 37.2	n9.724	n9.510
Dec. 30 9 12 30	8	3	−2 0.17	−1 50.2	5 42 55.28	+31 23 23.9	n9.374	0.320
30 11 38 50	8	2	−1 50.25	−5 10.7	5 43 5.20	31 20 3.4	8.897	0.242
31 7 49 27	9	6	+1 41.42	−3 58.7	5 44 31.95	30 57 40.0	n9.575	0.458
31 8 11 56	10	6	+0 28.23	+1 29.3	5 44 33.79	+30 56 50.2	n9.533	0.421
1887			☄e 1886 (FINLAY. Periodic).					
Jan. 21 8 33 21	11	21 , 7	−1 30.70	+2 3.0	1 25 55.56	+10 26 7.5	9.516	0.705
27 9 20 24	12	10 , 10	+0 11.34	+0 53.3	1 50 55.59	+13 3 59.1	9.584	0.704
Feb. 12 10 24 16	13	7	+1 38.25	+4 40.9	2 51 20.68	+18 30 14.8	9.648	0.713
13 9 15 22	14	10	+2 40.98	−0 46.6	2 54 40.87	18 45 44.4	9.594	0.660
25 9 34 28	15	8	+1 54.16	+0 24.7	3 34 31.22	+21 28 47.1	9.629	0.659
1888			☄f 1887 (OLBERS).					
Jan. 15 17 14 11	16	14	+2 7.42	+5 52.2			n9.589	0.786
15 17 14 11	17	14	−0 55.51	+4 52.6			n9.589	0.786
1888			☄a 1888 (SAWERTHAL).					
July 28 11 17 50	18	4	+2 39.75	−1 48.7	1 6 22.07	+53 6 12.7	n9.854	0.416

These include all my observations on comets no longer visible, that are hitherto unpublished. The unfortunate delay in the publication of results for comet 1880 *e* is due to a series of oversights and accidents which it is not worth while to recall. The two observations of comet *Olbers* are by Mr. H. V. EGBERT.

The comparisons for comet 1880 *e* from Oct. 11 to Nov. 25, inclusive, and for comet 1886 *e*, Jan. 21 and 27, are by filar-micrometer; the remainder are ring-micrometer comparisons.

The FINLAY comet in February was rather faint for the Albany instrument, as was comet 1888 *a* for the observation of July 28. In the latter case there seemed to be no well defined head; the comet was merely a nebulous streak.

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Mean Places of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
			1880.0		
	h m s	s	° ′ ″	″	
1	21 30 10.41	+3.79	+17 58 43.7	+29.5	Alb. Mer. Obs. (2)
2	21 48 14.59	3.57	28 34 0.2	33.5	" " " (1)
3	21 56 53.86	3.56	31 21 20.7	34.6	" " " (1)
4	22 17 40.16	3.63	36 46 35.3	36.7	" " " (2)
5	22 49 22.74	3.85	43 40 7.1	39.0	" " " (1)
6	1 21 21.71	6.27	54 39 23.0	35.9	" " " (2)
7	2 16 52.20	7.08	54 42 33.2	30.9	" " " (1)
8	5 44 48.64	6.81	31 25 12.1	2.0	Weisse's Bessel 1429
9	5 42 43.74	6.79	31 1 36.4	2.3	Weisse's Bessel 1358
10	5 43 58.78	+6.78	+30 55 18.8	+ 2.1	Leiden A.G.Z. (1)
			1887.0		
11	1 27 26.64	— .38	+10 24 10.0	— 5.5	Alb. Mer. Obs. (2)
12	1 50 44.58	.33	13 3 11.3	5.5	" " " (2)
13	2 49 42.66	.23	18 25 39.9	6.0	" " " (2)
14	2 52 0.13	.24	18 46 37.0	6.0	" " " (2)
15	3 32 37.29	— .23	+21 28 28.6	— 6.2	" " " (2)
			1888.0		
16	17 5 35.5	—1.68	— 3	+ 4.1	S.DM. —2°.4311
17	17 8 37.9	—1.69	— 2 59	+ 4.1	S.DM. —2°.4319
18	1 3 40.18	+2.14	+53 8 9.1	— 7.7	Oe A. 1160

ON THE OBSERVATION OF THE FAINTER MINIMA OF THE TELESCOPIC VARIABLES.

By S. C. CHANDLER.

The particular in which our knowledge of the variables is most lamentably defective relates to the character of the light-variations of those stars which, in their fainter phases, are invisible in ordinary telescopes. A very large proportion, fully one-half, of the periodical variables go below the reach of instruments of 6 or 7 inches aperture, which is about the size employed by the observers who have done most of the valuable and systematic work in this field. Probably not a few of them wane to a point which would tax the powers of the largest existing refractors, even if they do not disappear altogether. Yet the larger telescopes have been brought into the service not at all, or only in the most desultory fashion, albeit it is one entirely worthy of them. Indeed, taking a broad and impartial view of the relative importance, from a cosmological stand-point, of the various researches which would best utilize the optical power of the great telescopes, the one here indicated does not, it seems to me, occupy a secondary place.

Very likely one reason why the larger instruments have not yet been turned to investigations of this sort has been the fear of losing much time in identifying the variables near minimum; and another reason has been entire ignorance of the times of minima, an approximate knowledge of which is necessary to concentrate the observations effectively, and avoid the waste of effort involved in following phases of light-variation which can be seen in smaller and more easily handled telescopes.

In the hope that, if means were furnished ready to hand for economizing the labor of observation, some of our large refractors might be directed to this highly interesting and important work, I have undertaken the present article to supply the data to facilitate it.

First are given, for all the stars of my catalogue whose minimum brightness is less than the thirteenth magnitude, and for which Schönfeld's or my observations furnish the means, the positions of the smaller stars near the variables visible in telescopes of moderate size. These small stars were filled in by allineation upon my charts at the telescope, merely for the identification of the variables during their fainter phases; the magnitudes here given, therefore, are

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not to be treated as careful estimates or measurements, but rather as rude readings from the charts. The same is true of the differences of position from the variables, indicated in the list. But I believe them to be in all cases accurate enough to identify the latter beyond doubt. To distinguish between the data taken from my own charts and those given by SCHÖNFELD, which are doubtless more carefully assigned, they are followed by the symbols (C) and (S), respectively. Following the stars of identification are brief remarks as to the probable minimum brightness. Preceding the names of the variables are their numbers in my catalogue.

DATA FOR IDENTIFICATION AND MINIMUM BRIGHTNESS.

112 *R* Andromedae. 12^M pr 3^s, $2'$ S; 9^M pr 31^s on parallel; (C). Min. below 12.8^M.

114 *S* Ceti. 12^M foll 2^s, $4'.5$ S; 12^M pr 3^s, $6'$ N; (C). Min. below 12.5^M.

432 *S* Cassiopeae. 9.6^M foll 20^s, $2'$ S; (S). 12^M pr 15^s, $0'.3$ S; (C). My observations indicate min. not much less than 13.5^M.

466 *U* Piscium. For stars of identification see *AN* 99, 114. Min. 14^M?

513 *R* Piscium. 11^M foll 8^s, $0'.5$ N; 9^M pr 9^s, $4'$ N; (C). Min. below 12.5^M.

715 *S* Arietis. 9.10^M pr 10^s, $6'$ S; 10.11^M foll. 5^s, $4'.5$ N; (C). Min. 14^M?

845 *R* Ceti. 11^M pr 12^s, $5'$ N; (C). I have one min. at 13.5^M, preceding following max. 60–70 days.

1222 *R* Persei. 12^M foll 5^s, $0'.2$ S; 12^M foll 4^s, $1'.2$ S; 12^M pr 12^s, $0'.5$ S; (C). SCHÖNFELD puts min. at 12.5^M; I have one min. at 13.5^M. The star remains two months below 12^M.

1577 *R* Tauri. 8^M pr 15^s, $5'.5$ S; 10^M foll 3^s, $2'$ N; (C). Star disappears in my $6\frac{1}{4}$-inch, also in Pulkowa heliometer, $7\frac{1}{2}$-inch.

1582 *S* Tauri. 11.12^M foll 9^s, $1'$ S; 11.12^M foll 4^s, $0'.7$ S; 12^M pr 6^s, $1'$ N; (C). Remains only two months brighter than 12^M, according to SCHÖNFELD.

1717 *V* Tauri. 12.13^M foll 11^s, $1'$ S; 11.12^M foll 10^s, $3'.5$ N; (C). Min. below 13.5^M.

1761 *R* Orionis. 11^M foll 11^s, $0'.3$ N; 12^M pr 7^s, $1'$ S; (C). From light-curve near min. I think it doubtful that star goes below 13.5^M.

1944 *S* Orionis. 10^M about $1'$ N; 9.5^M pr 2.5^s, $0'.4$ S; (S). I have one min. at 13.5^M.

2100 *U* Orionis. Min. below 12^M.

2478 *R* Lyncis. 10^M foll 20^s, $2'.3$ N; 10^M pr 11^s, $3'.5$ N; (C). Min. below 13^M.

2528 *R* Geminorum. 12^M $2'.5$ N; 12.13^M pr 4^s, $1'$ S; 9^M foll 25^s, $3'$ N; (C). Min. probably not below 14^M, by my observations.

2684 *S* Canis min. 9.5^M foll 19^s, $4'$ N; 9.3^M pr 25^s, $3'$ N; (C). Min. certainly less than 11^M.

2691 *T* Canis min. 12.7^M pr 1^s, $0'.3$ S; 12.2^M foll 4^s, $0'.1$ N; (S). Min. less than 13.5^M.

2742 *S* Geminorum. 11.5^M foll 4^s, $0'.6$ S; 12^M pr. 5^s, $1'.6$ N; (S). Min. less than 13.5^M.

2780 *T* Geminorum. 12.13^M pr 1^s, $2'.3$ S; 11^M pr 12^s, 3 N; (C). SCHÖNFELD finds its min. too faint for the Mannheim refractor. I have observed one min. at 13.5^M.

2857 *U* Puppis. 10^M foll 26^s, $4'$ N; 11^M pr 16^s, $1'.5$ N; 13^M foll 2^s, $1'.5$ S; (C). Min. certainly less than 14^M.

2946 *R* Cancri. 10^M foll 6^s, $4'.4$ S; (S). 12^M pr 4^s, $1'.5$ S; (C). SCHWERD's min. of 1830 lies 125 days before max. Min. below 11.7^M.

2976 *V* Cancri. 11^M foll 4^s on parallel; 10.5^M foll 18^s, $0'.3$ N; (S). Min. below 12^M.

3060 *U* Cancri. 11^M pr 3^s, $7'$ N; (C). Disappears in Mannheim refractor, also in mine, and in CHACORNAC's 9-inch.

3170 *S* Hydrae. 11^M pr 12^s on parallel; 12^M foll 7^s, $0'.3$ N; (C). Min. below 12.2^M.

3184 *T* Hydrae. 10^M foll 6^s, $3'$ N; 10.11^M pr 4^s, $2'.5$ N; (C). Min. below 13^M.

3477 *R* Leonis min. 10.11^M foll 10^s, $2'$ N; (C). SCHONFELD has seen no min.; my observations show slow variations at about 13^M, when the star is possibly near min.

3567 *V* Leonis. 11.12^M foll 5^s, $1'.2$ N; (C). Disappears at min. in my $6\frac{1}{4}$-inch.

3890 *W* Leonis. For stars of identification see *AN* 99, 114. Min. 14^M?

3994 *S* Leonis. 11.5^M foll 6^s, $1'.7$ S; (S). Min. below 13^M.

4315 *R* Comae. 7.8^M pr 13^s, $2'.2$ N; (S). Min. below 13.5^M.

4407 *R* Corvi. 8^M foll 5^s, $3'.5$ S; 10^M pr 5^s, $0'.5$ N; 8^M foll 18^s, $1'$ S; (S). Increase after min. rapid, by my observations.

4492 *Y* Virginis. 8^M foll 19^s, $1'$ S; 11^M foll 12^s, $2'.5$ N; (C). Remains about 70 days below 12^M, by my observations. Min. probably below 14^M.

4816 *V* Virginis. Star isolated, and identification easy. Min. below 13^M.

5070 *Z* Virginis. 9^M pr 12^s, $2'$ S; 10^M pr 7^s, $2'$ N; (C). Min. below 14^M.

5430 *T* Librae. 10.11^M foll 7^s, on parallel; 13^M pr 4^s, $0'.2$ N; 13.14^M pr 1^s, $1'$ N; (C). Min. below 13.5^M.

5494 *S* Librae. 13^M pr 2^s, $2'$ N; 12.13^M foll 5^s, $2'.5$ N; (S). Min. below 13^M.

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5501 *S* Serpentis. 11^M pr 8^s, 0'.5 N; 12.7^M foll 2^s, 0'.4 N; (S). Min. 12.5^M?

5677 *R* Serpentis. Star isolated and identification easy. SCHÖNFELD thinks it doubtful if min. is less than 12^M, but I have observed a min. as faint as 13^M. It remained 100 days below 12^M.

5688 *R* Librae. 12^M pr 3^s, 1'.2 S; (S). Min. below 13^M.

5770 *R* Herculis. No difficulty in identification. Min. below 13^M.

5795 *W* Scorpii. 10^M pr 8^s, 1' N; 10^M foll 10^s, 3' S; (C). Min. 14.5^M?

5830 *R* Scorpii. 8^M per 24^s, 2' N: 9^M foll 10^s, 3' N; (C). Increase from 12^M rapid.

5831 *S* Scorpii. 9.4^M foll 9^s, 0'.2 N; (S). Min. below 13^M.

5856 *W* Ophiuchi. 11^M pr 13^s on parallel; 12^M foll 13^s, 4' N; 10^M foll 34^s, 1' N; (C). Min. below 13.5^M.

5928 *T* Ophiuchi. 10^M foll 5^s, 9' S; 10^M pr 5^s, 2'.5 S; (C). Invisible at min. in Mannheim refractor, also in mine.

5931 *S* Ophiuchi. 11.12^M pr 6^s, 3' N; 12^M pr 13^s, 0'.2 N; (C). Min. below 13^M.

5955 *R* Draconis. 8.5^M foll 35^s, 1'.5 S; 11^M foll 2^s, 3' S; (C). Min. probably not much below 13^M.

6132 *R* Ophiuchi. 10.11^M foll 6^s, 4' S; 10.11^M pr 2^s, 6' S; also a small nebula, not in HERSCHEL's *General Catalogue*, or DREYER's *Supplement*, foll about 36^s, 2' S; (C). Min. certainly below 12^M.

6624 *T* Serpentis. 11.12^M foll 3^s, 0'.1 N; (S). Min. below 13.5^M.

6903 *T* Sagittarii. 11.12^M foll 10^s, 0'.5 N; (C). I have no min., but have followed it to 11^M, when it was still rapidly decreasing.

6905 *R* Sagittarii. 11.3^M pr 1^s, 0'.4 S; 10.8^M pr 4^s, 1' N; (S). Min. certainly less than 12^M; I suspect there are secondary fluctuations.

6921 *S* Sagittarii. 11^M foll 24^s, 2'.5 S; (C). Min. below 13^M.

7045 *R* Cygni. θ Cygni pr 22^s, 0'.7 N; 9^M foll 2^s, 1'.5 N; (S). Min. below 13^M. POGSON thought min. precedes max. 155 days.

7220 *S* Cygni. 8.9^M foll 1^s, 0'.8 N; (S). It rises rapidly from 12^M, by my observations.

7234 *R* Capricorni. 13^M dist. 20'', P = 355°; (S). Min. below 13^M.

7252 *W* Capricorni. For stars of identification see *AN* 109, 120. Min. 14^M?

7444 *T* Delphini. 11^M pr 3^s, 2'.7 N; 10.1^M foll 12^s, 0'.1 N; (S). Decrease more than usually rapid. Min. below 13^M.

7455 *U* Capricorni. 8.5^M foll 20^s, 7' N; 10^M pr 15^s, 6' S; (C). Min. below 13^M.

7571 *V* Capricorni. For stars of identification see *AN* 109, 121. Min. 14^M?

7577 *X* Capricorni. For stars of identification see *AN* 109, 122. Min. 14^M?

7659 *T* Capricorni. 9^M pr 5^s, 3'.9 N; (S). Min. below 13^M.

7944 *T* Pegasi. 11^M pr 13^s, 1'.5 N; (C). R.A. of DM 6^s too small. SCHÖNFELD has observed no min., but found the variation near 11^M very slow. My observations show that min. must be less than 13^M.

8153 R Lacertae. 9.3^M foll 20^s, 2'.8 N; 11^M foll 7^s, 2'.8 N; 11^M pr 13^s, 2'.5 N; (C). Increase from 13^M to 10^M very rapid.

8230 *S* Aquarii. 7.5^M foll 31^s, 4' N; 10^M foll 9^s, 3' S; (C). Decrease from 10^M rapid. Min. below 12.5^M.

8290 *R* Pegasi. 11^M foll 10^s, 0'.2 N; 10.11^M pr 9^s, 3' N; (C). Min. below 13^M.

8373 *S* Pegasi. No faint stars near. Increase from 11^M rather slow. Min. below 13^M.

8512 *R* Aquarii. Identification easy. Increase from 10^M quite rapid. No min. yet observed.

8597 *V* Ceti. For stars of identification see *AN* 109, 123. Min. 14^M?

In connection with the foregoing is given a hypothetical ephemeris, synchronistically arranged, of all the minima which will occur during the remainder of the current year and in 1889. Since the epochs of minimum are unknown by direct observation, the predictions must be based upon assumptions as to their position with reference to the known maxima, made in accordance with our knowledge of the general character of the light-curves. The average ratio of the time of increase of light to that of decrease, among the telescopic long-period variables, is about 5 to 6. It is accordingly assumed, in constructing the ephemeris, that the minimum precedes the maximum by 0.45 of the period. By an investigation shortly to be published I think I have discovered, among other things, a curious relation between the forms of the light-curves and the periods by which it might be possible to make closer guesses at the times of minima than are contained in the ephemeris; but it does not seem worth while to try merely for the present purpose.

In addition to the approximate time of minimum is given an estimate of the probable limits of uncertainty, in the figures preceded by the plus-or-minus sign. It may be reasonably expected that if observations are begun about the earlier limit of time thus indicated, and continued until the later one, the unknown minimum will be found included. I will simply add that, in stars with periods between five and ten months, and greater than thirteen months, I should expect a tendency to anticipate the predicted times, and in stars of from ten to thirteen months a tendency to lag behind.

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HYPOTHETICAL EPHEMERIS OF FAINT MINIMA OF TELESCOPIC LONG-PERIOD VARIABLES.

	1888 October	d	d
2780	*T* Geminorum	22	±30
7944	*T* Pegasi	24	40
7444	*T* Delphini	29	35

	1888 November		
2478	*R* Lyncis	1	±20
2742	*S* Geminorum	2	30
3567	*V* Leonis	3	30
3060	*U* Cancri	7	35
8290	*R* Pegasi	8	40
1944	*S* Orionis	10	45
5955	*R* Draconis	13	30
845	*R* Ceti	14	20
7571	*V* Capricorni	14	35
8373	*S* Pegasi	15	35
7220	*S* Cygni	15	35
3890	*W* Leonis	16	40
2976	*V* Cancri	21	30
7577	*X* Capricorni	24	25

	1888 December		
5494	*S* Librae	4	±20
7234	*R* Capricorni	12	35
5831	*S* Scorpii	17	20
5795	*W* Scorpii	31	25

	1889 January		
1761	*R* Orionis	13	±40
6624	*T* Serpentis	19	35
112	*R* Andromedae	20	45
4407	*R* Corvi	25	35

	1889 February	d	d
513	*R* Piscium	2	±35
6905	*R* Sagittarii	11	30
5856	*W* Ophiuchi	13	35
1222	*R* Persei	13	25
6921	*S* Sagittarii	14	25
466	*U* Piscium	16	35
3170	*S* Hydrae	17	30
5070	*Z* Virginis	20	30
2528	*R* Geminorum	25	20
3994	*S* Leonis	28	20

	1889 March		
3477	*R* Leon. min.	3	±40
7455	*U* Capricorni	8	20
2684	*S* Can. min.	12	35
1717	*V* Tauri	13	20
4315	*R* Comae	16	40
5931	*S* Ophiuchi	18	25
5430	*T* Librae	22	75
432	*S* Cassiopeae	28	60

	1889 April		
2857	*U* Puppis	16	±35
4492	*Y* Virginis	19	15
715	*S* Arietis	24	30

	1889 May		
7045	*R* Cygni	1	±20
2691	*T* Can. min.	2	35
5688	*R* Librae	5	75
6903	*T* Sagittarii	7	40
114	*S* Ceti	9	35

	1889 May	d	d
4816	*V* Virginis	10	±25
8597	*V* Ceti	11	30
5830	*R* Scorpii	20	25
7659	*T* Capricorni	26	30

	1889 June		
8230	*S* Aquarii	10	±30
6132	*R* Ophiuchi	11	30
2100	*U* Orionis	13	40
5494	*S* Librae	14	20
5928	*T* Ophiuchi	21	40
7577	*X* Capricorni	22	25
3184	*T* Hydrae	26	30
2946	*R* Cancri	26	20

	1889 July		
5770	*R* Herculis	6	±35
1577	*R* Tauri	7	35
1582	*S* Tauri	12	40
5955	*R* Draconis	17	30
5677	*R* Serpentis	31	20

	1889 August		
2780	*T* Geminorum	6	±30
3567	*V* Leonis	10	30
5795	*W* Scorpii	11	25
2976	*V* Cancri	19	30
2742	*S* Geminorum	23	30
1717	*V* Tauri	30	20

	1889 September		
3994	*S* Leonis	5	±20
3060	*U* Cancri	8	35

	1889 September	d	d
1222	*R* Persei	12	±25
8153	*R* Lacertae	18	35
7571	*V* Capricorni	20	35
7444	*T* Delphini	26	35
7455	*U* Capricorni	27	25
8373	*S* Pegasi	29	35
5501	*S* Serpentis	29	40

	1889 October		
6921	*S* Sagittarii	2	±25
7220	*S* Cygni	6	35
845	*R* Ceti	14	20
8512	*R* Aquarii	15	40
3170	*S* Hydrae	31	30
7944	*T* Pegasi	31	40

	1889 November		
7252	*W* Capricorni	2	±45
5931	*S* Ophiuchi	7	25
6905	*R* Sagittarii	9	30
2478	*R* Lyncis	16	20
8290	*R* Pegasi	21	40
7234	*R* Capricorni	24	35

	1889 December		
4407	*R* Corvi	8	±35
3890	*W* Leonis	16	40
5070	*Z* Virginis	20	30
5494	*S* Librae	24	20
6624	*T* Serpentis	27	35
5830	*R* Scorpii	31	25
1944	*S* Orionis	31	45

All that need be said as to the kind of observation necessary is that comparisons by ARGELANDER's method will be the most useful and precise of any that can be obtained. And here is one great advantage which this class of work possesses, namely, that it can be prosecuted without special apparatus, and can go on simultaneously with micrometrical or other work, without disturbance of adjustments or change of eyepiece.

It only remains to add that, as the observer will be at work on new ground, he may feel entirely untrammeled in the selection of comparison-stars; except that it will be well to include, if practicable, the identification-stars above given in the brighter parts of his scale, as they have largely been similarly used as the fainter stars of the scale with my telescope (and probably also by SCHÖNFELD), and will therefore eventually serve as a term of comparison.

Cambridge, 1888 *October* 11.

SUN-SPOT OBSERVATIONS, MARCH TO OCTOBER, 1888,

BY PAUL S. YENDELL.

The subjoined observations were undertaken at the rooms of the Boston Scientific Society in Boston, with the view of keeping a continuous record of the number of spots visible daily with a small aperture.

The telescope used is a refractor by Clark, of 3 inches aperture and 43 inches focal length; the observations were at first made by viewing the image of the sun reflected from an unsilvered glass plane belonging to the Society, an eyepiece of 1 inch equivalent focus being used, giving a power of 43. The plane proving unsatisfactory, was discarded from May 3, and the telescope placed at an east window, where the observations have since been made, the object-glass being stopped down to 2 inches to avoid the injurious effect of glare upon the eye, the shade-glass used having been originally intended for a smaller aperture; on June 29 an eyepiece of $\frac{3}{4}$-inch power was substituted for the 1 inch previously used, in order to facilitate the counting of the spots; this combination of aperture and eyepiece has since been used continuously. An observation has been made every day on which the sun has been visible from the window, except in cases of my unavoidable absence. So far as can be judged from the monthly averages, no indication of any definite increase in the number of spots has yet been afforded by the observations.

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Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.
1888	h m			1888	h m			1888	h m			1888	h m		
Mar. 17	23 15		1	May 18	20 15	1	4	July 2	20 35	0	0	Aug. 23	20 30	0	0
18	22 15		1	21	20 15	1	3	3	20 30	0	0	24	20 30	0	0
22	22 15	1	2	22	20 45	1	2	5	20 30	0	0	25	20 30	1	2
23	23 15	0	0	23	20 35	0	0	6	20 30	1	2	27	20 30	1	3
24	22 30	0	0					7	20 30	0	0	28	20 30	0	0
25	22 15	0	0	June 2	20 30	0	0	9	20 35	0	0	29	20 35	1	5
31	0 15	0	0	4	20 30	0	0	10	20 25	0	0	30	20 30	2	8
	22 15	0	0	5	20 30	0	0	11	20 40	0	0	31	20 35	1	4
				6	20 30	0	0	12	20 30	0	0				
Apr. 3	22 15	0	0	7	20 30	0	0	13	20 30	2	4	Sept. 3	20 30	1	5
4	22 15	0	0	8	20 45	0	0	14	20 30	2	8	4	20 30	1	5
7	0 15	0	0	9	20 30	0	0	16	20 30		2	5	20 25	1	3
	23 15	0	0	11	21 0	1	9	17	20 30		1	6	20 30	1	2
9	23 15	0	0	12	20 30	1	6	21	20 40	0	0	7	20 30		1
10	23 15	0	0	13	20 35	0	0	23	21 30	0	0	8	21 05		1
12	23 15	0	0	14	20 45	2	3	24	20 30	0	0	11	21 45	1	6
13	23 15	0	0	16	20 30	2	4	25	20 30	0	0	13	20 30	1	8
17	22 15	0	0	19	20 45	0	0	26	20 30	0	0	14	20 30	1	2
25	23 15		2	20	20 30	0	0	28	20 55	0	0	15	20 25		1
27	23 15		1	21	20 35	0	0	30	20 30	0	0	22	23 25	1	2
28	23 15	0	0	22	20 35	0	0	31	20 30	0	0	24	20 25		1
30	22 15	0	0	23	20 20	0	0					25	20 20		1
				26	20 35	2	5	Aug. 9	21 45	1	2	27	20 30		1
May 3	23 15	0	0	27	20 45	1	7	10	20 40	0	0	28	23 0		1
10	20 45			29	20 45	0	0	11	20 30	0	0	29	20 30		0
16	20 15	1	9	30	20 30	0	0	21	20 30	1	2				
17	20 15	1	12					22	20 30	1	2				

NOTES.

April 7. Light clouds. — April 12. Hazy; storm arising. — April 28. Light clouds passing. — April 30. Plane mirror very unsatisfactory. — May 10. Observations *direct*, with same aperture and eyepiece, but without mirror, which was this day discarded and not afterwards used. — May 16. Objective stopped down to two inches, and so used in all the following observations. — May 17. Two large spots, and the rest small. — May 18. Same group; the following large spot has disappeared. — April 20. Fine aurora. — April 22. Spots near W. limb. — June 14. Cloudy. — June 21. Thin cloud. — June 27. Changed eyepiece for ⅜-inch. — June 29. Observed through thin cloud. — July 21. Thin cloud. — July 28. One large *facula*. — August 9. Many *faculae*. — August 21. Hazy; clouds passing. — August 22. Seeing fine. — August 23. Seeing rather poor. — August 29 and 30. Air unsteady. — August 31 and Sept. 3. Air very unsteady. — Sept. 4. Seeing very bad. — Sept. 6. Thin cloud; seeing poor. — Sept. 7. Seeing poor. — Sept. 8. Seeing good. — Sept. 14. Seeing bad. — Sept. 15. Seeing good. — Sept. 25. Thin cloud; image sharp. — Sept. 27. Seeing uncommonly good.

Boston, 1888 *Sept*. 30.

ELEMENTS OF COMET 1888 *c*,

By WILLIAM C. WINLOCK.

From the observation at Munich, August 9, Kiel, August 24, and Albany, September 6, I have computed the following elements, — corrections for aberration and parallax being derived from the elements given by Kreutz in the *Astronomische Nachrichten*, No. 2855.

$$T = 1888 \text{ July } 31.15493 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 59^\circ\ 13'\ 53''.3 \\ \Omega &= 101\quad 29\quad 48\ .3 \\ i &= 74\quad 11\quad 50\ .5 \end{aligned}\right\} 1888.0$$

$$\log q = 9.955370$$

Middle place (O—C) $\Delta\lambda \cos\beta = -2''.3$ $\log \cot J = 9.420019$

$\Delta\beta = -6\ .8$ $\log \cot J_0 = 9.420019$

Equatorial Coordinates.

$$x = [9.477914] \sec^2 \tfrac{1}{2} v (275^\circ\ 59'\ 11''.9 + v)$$
$$y = [9.954377] \sec^2 \tfrac{1}{2} v (174\quad 56\quad 14\ .4 + v)$$
$$z = [9.930948] \sec^2 \tfrac{1}{2} v (\ 83\quad 35\quad 55\ .8 + v)$$

Washington, 1888 *October* 9.

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FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *c*,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY,

BY F. P. LEAVENWORTH.

1888 Haverford M.T.	✱	No. Comp.	☄ — ✱ Δα	☄ — ✱ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Aug. 10 9 10 29	1	6 , –	+5 23.18		10 31 11.20		9.743	
10 9 30 57	1	– , 2		+5 18.7		+44 50 50.1		0.830
14 8 49 5	2	6 , –	–1 58.10		11 2 7.57		9.774	
14 9 10 28	2	– , 3		+0 39.7		44 32 17.0		0.790
14 8 49 5	3	6 , –	+1 42.28		11 2 7.52		9.774	
22 8 50 50	4	15 , 5	–0 17.18	+1 54.7	12 4 25.72	42 13 6.5	9.774	0.720
24 8 19 31	5	24 , 8	+0 56.24	–2 7.4	12 19 17.91	41 18 22.8	9.779	0.658
30 8 14 4	6	9 , 3	+0 33.67	–0 57.0	13 1 44.86	37 50 32.3	9.758	0.633
30 8 5 25	7	18 , 6	–0 21.13	–1 7.1	13 1 42.38	+37 50 58.8	9.757	0.618

Mean Places for 1888.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	10 25 48.74	–0.79	+44 45 27.9	+1.26	Radcliffe 2509
2	11 4 6.42	0.76	44 31 34.3	2.90	Weisse's Bessel 13
3	11 0 26.09	0.76			Radcliffe 2620
4	12 4 43.48	0.59	42 11 6.6	5.06	Weisse's Bessel 47
5	12 18 22.22	0.56	41 20 24.6	5.58	" " 346
6	13 1 11.61	0.42	37 51 22.2	6.96	" " 1173
7	13 2 3.93	–0.42	+37 51 58.9	+6.96	" " 1187

OBSERVATIONS OF SHORT-PERIOD VARIABLES IN *SAGITTARIUS*,

BY PAUL S. YENDELL.

I herewith communicate the results of observations made during the past season, by ARGELANDER's method, upon the well-known group of variables of short period in *Sagittarius*. The results are stated in decimals of a day, in Cambridge mean time, and weights are assigned to express the relative certainty of the determinations.

W Sagittarii.

Forty-six observations of this star, from June 12 to September 29, yield the following times of maxima and minima.

MAXIMA	p	MINIMA	p
1888 June 11.38	3	1888 June 16.45	4
19.0	3	July 1.33	3
26.62	3.5	8.45	5
July 3.9	5	16.33	5
11.5	4.5	23.86	3
19.1	3	Aug. 23.15	3
26.8	2.5	Sept. 7.7	4
Aug. 10.8	1.5	23.4	2
26.16	5		
Sept. 2.9	2.5		
10.45	2		
26.4	4.5		

The observed range of variation in magnitude differs somewhat from that given by SCHÖNFELD, being from 4.57 at maximum to 5.82 at minimum — a range of 1.25 magnitude; these values are deduced from a careful comparison of the light-curve with the best obtainable magnitudes of the comparison-stars used.

X Sagittarii.

Forty-one observations of this star, obtained from June 12 to September 29, give nine maxima and eight minima. The range of variation observed, deduced as in the case of *W Sagittarii*, falls far short of that given by SCHÖNFELD, being from 5.0 at maximum to 5.83 at minimum. The observed times of maxima and minima are as follows:

MAXIMA	p	MINIMA	p
1888 June 30.4	2	1888 June 27.9	3
July 7.5	4	July 4.84	3
14.58	4	11.7	4
21.6	1	26.5	2.5
Aug. 11.9	1	Aug. 29.42	2
25.	5	Sept. 5.88	2
Sept. 1.48	1	12.36	2
8.8	3	25.38	4
28.95	4		

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Y Sagittarii. 6573

A series of forty-two observations of this variable, from June 12 to September 29, gives eleven maxima and six minima. The light-curve, period, and range of variation in magnitude deduced, agree well with Mr. SAWYER's results. The times of maxima and minima of this and the two preceding stars were obtained by POGSON's method and the use of mean light-curves. The times observed are as follows:

MAXIMA	p	MINIMA	p
1888 June 14.6	2.5	1888 June 25.1	2
26.4	4	July 5.3	4
July 2.0	3	12.3	4
7.08	4	24.0	4
13.9	3.5	Aug. 27.9	5
25.6	3	Sept. 13.8	3.5
Aug. 23.3	4		
29.4	5		
Sept. 3.75	2		
9.6	3.5		
22.68	4		

U Sagittarii. 6636

This star was taken up rather late in the season, and on account of its situation in a coarse cluster it was necessary to use the telescope for its observation, though it is bright enough to be well observed with the field-glass if separated from its neighbors. The star was not seen at or near minimum, the observations, twenty in number, grouping themselves about the maxima, of which five were obtained by the employment of POGSON's method, with the following results:

MAXIMA	p
1888 Aug. 24.37	4
31.0	2
Sept. 6.9	2
14.3	2
27.45	4

Dorchester, Mass., 1888 *October* 15.

OBSERVATIONS OF COMET 1888 *e*,

MADE AT THE LICK OBSERVATORY,

BY E. E. BARNARD.

[Communicated by permission of the Director.]

1888. Mt. Hamilton M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Sept. 25 16 24 41	7	5 , 7	+1 19.58	+7 49.4	6 43 57.78	+9 7 14.1	n9.364	0.633
26 16 36 3	7	8 , 6	+0 32.35	+1 36.5	43 10.70	+9 1 1.3	n9.342	0.633

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
7	6 42 36.97	{ +1.23 +1.38	+8 59 24.8	{ —0.1 0.0	⅓ (W.B. VI) 1234 + 2 Grant 1655

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THE

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OBSERVATIONS OF SOME SUSPECTED VARIABLE STARS,

BY EDWIN F. SAWYER.

During the past few years, I have accumulated, in connection with my observations of the known variables, a large number of observations of stars whose constancy of light has been suspected with more or less of reason, by various authorities. The number of such cases of supposed variation of light is already very large, and is constantly increasing. It is highly important that the confusion which is likely to arise in our knowledge of the variable stars from the undue increase of this list should be lessened, as much as possible, by their critical examination. Therefore, as soon as sufficient evidence has been obtained to establish with reasonable probability the constancy of light of any of these alleged cases of variabililty, it should be placed upon record. I have consequently selected a few of the stars which I have had under observation, where the negative evidence in regard to variability appears to be very strong, and present them in the following list. The notes relating to these stars have been taken bodily (by kind permission of the author) from Mr. CHANDLER's unpublished catalogue of suspected variables. The arrangement of the stars is in the order of right-ascension, the places being for the equinox of 1875. The observations represent not mere estimations, but actual comparisons with two or more neighboring stars; the magnitudes given being the average deduced values from Dr. GOULD's *Uranometria Argentina* and my own unpublished revision of this work.* In my earlier observations the estimations of brightness of colored stars are considered of less weight than in later observations, after more experience had been acquired in this work; discordant observations being less frequent after the years 1882 and 1883.

1. 142 (*U.A.*) *Ceti:* $1^h\ 19^m\ 31^s$, $-4°\ 36'.6$.

Of the six estimates made at Cordoba, three give its magnitude as 6.5, and one each as 6.7, 7.5 and 7.8. LALANDE, 6½; BESSEL, 8. "This is certainly variable" (*U.A.* p. 312).

This star has been very carefully watched, 33 observations having been obtained, as follows: 1881, 1; 1882, 5; 1883, 10; 1884, 2; 1885, 11; 1886, 2; and 1888, 2. These observations are very accordant, the extreme range being only from 6.5 to 6.8, and furnish no evidence of variability. If variable it must be of the *Algol*-type.

2. 185 (*U.A.*) *Ceti:* $1^h\ 45^m\ 17^s$, $-10°\ 57'.2$.

BESSEL, 5 or 6; BRADLEY, PIAZZI, and LALANDE, 3 (Notes to Berlin Charts). GOULD, who makes it 3.5, calls attention to these discordances, and also to the fact that *U.N.* and HEIS make it 3, while J. HERSCHEL makes it 4.9, a difference which would not be remarkable were it not that he estimated this star as fainter than τ^6, g and τ^5 *Eridani*, which are 3.9, 4.1, and 4.5, repectively, and only appreciably brighter than ϵ or ρ *Ceti*, which are 4.6 (*U.A.* p. 312).

My observations, 7 in number, were made in 1884 and 1886. On 1884, November 9 and 11, the estimates are 3.9 and 3.85. Five estimates in 1886, October 23, November 19, 21 and 26 give 3.7, and one estimate, November 27, gives 3.5. With the exception of the last observation the results are fairly accordant, considering the brightness of the star, and give no evidence of variation.

3. 204 (*U.A.*) *Ceti:* $1^h\ 57^m\ 24^s$, $-0°\ 56'.4$.

GOULD 5.9, from accordant determination by different observers in 1872; but one estimate in the previous year had been as low as 6.3. The star is neither in the *U.N.* nor in the Albany list; so that it could hardly have been as bright as 6.1 when the estimates were made for those works; but HEIS gives it as 6⅓. LALANDE as 7½ and 6; PIAZZI, 7; BESSEL, 6½; and in the *Durchmusterung* it is 7.3. These variations indicate a fluctuation through more than a unit (*U.A.* pp. 312–13).

I have six observations, as follows: 1882 January 29 and February 14, 6.1; 1884 January 26, 6.1; 1886 November 21, 26 and 28, 6.2, 6.2, 5.95. The observations are, with the exception of the last, very accordant, and furnish no evidence of change of light.

4. 283 (*U.A.*) *Ceti:* $4^h\ 54^m\ 7^s$, $-12°\ 43'.4$.

GOULD says "certainly variable," because Cordoba esti-

* Nearly ready for publication.

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mates vary from 4.8 to 5.7, and he designates it as *S Eridani*. *Histoire Céleste*, $5\frac{1}{2}$, 6; *U.N.* and HEIS, 6; BESSEL, 8, but clouds may have obscured it (*U.A.* p. 273). GORE has also found anomalies in its light (*S.S. Objects* p. 47).

Star somewhat difficult to observe, but I have 34 observations, distributed pretty uniformly between 1883 and 1888; two of them give 5.0 (1886 February 22 and 24), the rest all range between 5.1 and 5.3; which seems to demonstrate the constancy of the star.

5. 12 (*U.A.*) *Leporis:* $5^h\ 0^m\ 10^s$, $-22°\ 32'.4$.

Given in *U.A.* p. 204, as 3.1, with "variable?" appended. Nothing in notes to Catalogue by way of explanation. CHANDLER's observations, 1881-1882, seem to indicate variability between 3.1 and 3.9.

J. HERSCHEL's sequences 20, 32 and 37, all make this star brighter than γ or μ *Leporis* (Cape obs. p. 319).

This is a bright colored star, and consequently difficult to observe, notwithstanding which, my 8 observations in the years 1882, 1886 and 1888 are quite accordant, ranging only from 3.3 to 3.5, and give no indications of variability.

6. 81 (*U.A.*) *Orionis:* $5^h\ 23^m\ 23^s$, $-1°\ 11'.5$.

Estimates at Cordoba of this decidedly reddish star give from $4\frac{3}{4}$ to 6; it having been seen at these extremes, and at all the intermediate stages. Albany, 5.3; D'AGELET, $5\frac{2}{3}$; LALANDE and PIAZZI, 5; ARGELANDER, 5; HEIS, $5\frac{1}{4}$; DM., 5.5; SCHJELLERUP, 5.5 (*U.A.* p. 328). FLAMMARION assigns the discovery of variability to FALB, on what authority is not known (*Les Étoiles* p. 700). COPELAND and DREYER, 5.0, 5.8, 6.0 (*Dunsink Obs.* IV, 46).

I have six observations, as follows: 1882 March 15, 5.3; 1886 February 28, 5.7; 1887 February 13, 14 and 22, 5.9, 5.7, 5.7, and 1888 February 13, 5.7. With the exception of the first estimation made in 1882, these are accordant, and the evidence of variability is slight.

The intense color of the star renders observations very difficult.

7. 101 (*U.A.*) *Orionis:* $5^h\ 28^m\ 15^s$, $+9°\ 50'.9$.

Used at Cordoba as a standard for 3.5; but subsequent observations indicate variations of about half a magnitude.

My 8 observations are confined to the years 1883 and 1884, but give, very accordantly, either 3.35 or 3.4, and furnish no evidence of variability.

8. 111 (*U.A.*) *Orionis:* $5^h\ 29^m\ 21^s$, $-3°\ 20'.2$.

At Cordoba 6.7 in 1871, 6.8 in 1873, 6.9 in 1877, and at the close of 1878 was not above 7.0; but as these estimates were made by three different observers, too much stress ought not to be laid on the apparently progressive diminution. A stronger presumption of the variability of the star arises from its non-occurence in any of the catalogues to which I have access. It is brighter than *W.B.* V, 732 by a full unit of magnitude, and appears to be the one given by SCHMIDT as 8 in his catalogue of stars observed through a glass micrometer, published with Hour V of the Berlin Academy charts (*U.A.* pp. 329-330).

I have 30 observations of this star, extending from 1882 March 17 to 1888 February 13.

These observations are fairly accordant, fluctuating only from 6.6 to 6.9, and the evidence of variability from these observations appears very slight.

9. 161 (*U.A.*) *Orionis:* $5^h\ 53^m\ 48^s$, $-3°\ 4'.8$.

Cordoba estimates, 5.9 to 5.1, indicate variability. At Albany, also, 5.1; LALANDE, $6\frac{1}{2}$; BESSEL, 6; *U.N.*, $5\frac{1}{3}$; HEIS, $5\frac{2}{3}$ (*U.A.* p. 330).

I have observed this star six times. Five observations, 1886 February 28; 1887 February 13 and 22, April 13; and 1888 February 13, give a progressive brightening from 5.55 to 5.35. This range, however, is too small to furnish evidence of change. An observation in 1882, March 3, gives 4.9. This I consider an error of observation, the other estimations being so fairly accordant. It would be well, however, to give further attention to this star, which, by the way, is difficult to observe owing to its brightness and color.

10. 185 (*U.A.*) *Orionis:* $6^h\ 13^m\ 44^s$, $-2°\ 53'.6$.

This orange star, estimated as 7, 5, and 6 by BIRMINGHAM, is suggested as variable by him on account of its having been missed by previous observers of red stars (*M.N.* XXXIV, 253). GORE found it just visible to naked eye in 1875 (*S.S. Objects* 95). At Cordoba the estimates of its light range from 5.1 to 5.9; Albany, 5.4 (*U.A.* p. 331). BIRMINGHAM's α appears to be too large by one minute of time. In BIRMINGHAM's *Catalogue of Red Stars* there seems to be a curious confusion of this star with *Bm.* 147, the place of which, for 1875, is $6^h\ 24^m\ 11^s$, $-2°\ 56'.3$; since he has given some observations against *Bm.* 147 which obviously pertain to *H.P.* 1189. Compare *M.N.* XXXIV, 253, with his *Catalogue of Red Stars*. It is possible that he has sometimes observed one star, and sometimes the other, and that the apparent discordances in his estimates of the latter (5-8) are due to this cause.

My six observations of this star are: 1882 March 17, 5.3; 1886 February 28, 5.9; 1887 February 13, 22, and March 13, 5.9, 5.95 and 5.9; 1888 February 13, 5.85. These, with the exception of the first, are very accordant. The star's brightness and color renders observations difficult, yet it will bear further watching.

11. 155 (*U.A.*) *Puppis:* $7^h\ 38^m\ 30^s$, $-28°\ 6'.9$.

Cordoba estimates, from 4.8 to 5.6. ARGELANDER called it 5.0 (*Bonn Obs.* VI), but it is not in *U.N.*; HEIS, 6; BEHRMANN, 5 (*U.A.* p. 281).

My 25 observations extend from 1882 March 23 to 1888 March 29. On 1882 March 23, the star was estimated as

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bright as 5.0; 14 observations in 1883, from February 3 to April 4, give 5.8; 4 observations in 1884, from February 1 to March 22, range from 5.75 to 5.9. On 1886 March 7, the star was estimated 5.55, while 5 observations in 1887 and 1888 only range from 5.65 to 5.7. These observations, with the exception of the first made in 1882, are fairly accordant. The constancy of the star's light seems to be fairly established.

12. 56 (*U.A.*) *Hydrae:* $8^h\ 39^m\ 42^s$, $-1°\ 35'.8$.

Although estimated as 6.3 at Cordoba, it is not in *U.N.;* but at Albany was estimated as 5.9. HEIS, 6; DM., 7; BESSEL, 8 (*U.A.* p. 298); SANTINI, 7; LAMONT, 6.7; HOUZEAU, 6.

My observations are: 1884 April 27, 6.2; 1887 March 25, and May 9, 6.4; 1888 April 3, 6. and May 7, 6.5, 6.45 and 6.45. Extreme range 6.2 to 6.5. Evidence of variability very slight.

13. 50 (*U.A.*) *Puppis:* $9^h\ 2^m\ 34^s$, $-25°\ 21'.3$.

GOULD thinks there is reason to believe that this star is variable. The Cordoba estimates range from 4.3 to 5.1. ARGELANDER, in different zones, gives 4, 4½ and 5; but in *U.N.*, 5; LACAILLE, 6; PIAZZI, 5½; HEIS, 5; BEHRMANN, 6.5. Color light orange (*U.A.* p. 297). Observed at Dublin as 4.5 and 5.0 (*Dunsink Obs.* IV, 54).

I have 8 observations between 1884 and 1888, all within the limits 4.8–5.0, which apparently certify the star's invariability.

14. 66 (*U.A.*) *Pyxidis:* $9^h\ 21^m\ 18^s$, $-28°\ 14'.8$.

The magnitude apparently fluctuated more than once between 6.1 and 6.7 during the observations at Cordoba. LACAILLE, 6; BRISBANE, 6; ARGELANDER, in 1854, 6.0; BEHRMANN, 6 (*U.A.* p. 298). Not in *U.N.* or HEIS.

My six observations in 1886, 1887 and 1888, are very accordant, ranging only from 6.5 to 6.55. Light apparently constant.

15. 194 (*U.A.*) *Hydrae:* $9^h\ 59^m\ 2^s$, $-12°\ 27'.6$.

LALANDE, 5; PIAZZI, 5½; ARGELANDER and HEIS, 4⅔. Cordoba estimates vary from 4.5 to 5.2 (*U.A.* p. 299).

I have 33 observations, extending from 1882 February 14 to 1888 May 7, and they range only from 4.6 to 4.8. The constancy of this star's light seems fairly established.

16. 235 (*U.A.*) *Hydrae:* $10^h\ 30^m\ 11^s$, $-26°\ 1'.5$.

At Cordoba, 6.6; LACAILLE, 7; ARGELANDER in his zones 6½, and called by YARNALL 6.8. But BEHRMANN has it 6 (*U.A.* p. 299).

My 6 observations, extending from 1884 March 25 to 1888 May 7, range from 6.3 to 6.7. The star is, however, rather difficult to observe, there being no good comparison-stars closely adjacent; and to this cause the discordant results are attributed. Further observations are desirable.

17. 45 (*U.A.*) *Virginis:* $12^h\ 13^m\ 31^s$, $+0°\ 1'.7$.

GOULD thinks the brightness of this star has diminished in recent years, and that it varies between 3 and 4. At Cordoba only one estimate was as bright as 3.9. PTOLEMY, ULUGH BEY, and HEVELIUS, 3; TYCHO, 4; MAYER and PIAZZI, 3½; Albany Catal., 36 (*U.A.* p. 318).

My 6 observations, made during the years 1884 to 1888, range from 3.6 to 4.0. This being a bright star, and the comparison-stars necessarily scattered, the observations are difficult. Variation considered doubtful.

18. 30 (*U.A.*) *Corvi:* $12^h\ 23^m\ 45^s$, $-23°\ 0'.3$.

GOULD says this star seems variable from 5¾ to 6½, or lower; the Cordoba estimates, ranging from 5.8 to 6.5. PIAZZI, 7; TAYLOR, 6; JOHNSON, in 1859, 5.7; YARNALL, in 1867, 5.6; HEIS, 6½ (*U.A.* p. 318).

I have 8 accordant observations, made during the years 1882 to 1888; the extreme estimations being 6.25 and 6.45. The evidence of variability appears very slight.

19. 154 (*U.A.*) *Virginis:* $13^h\ 23^m\ 55^s$, $-5°\ 49'.4$.

Cordoba observations show indications of variation of about half a magnitude in this star (*U.A.* p. 319).

Of my 7 observations, made in the years 1882, 1886, 1887 and 1888, only one is discordant (6.7), the others ranging only from 6.3 to 6.45. I find no evidence of change in this star.

20. 165 (*U.A.*) *Virginis:* $13^h\ 28^m\ 2^s$, $-12°\ 34'.3$.

SCHMIDT found this June 6, 1866, while observing the smaller stars of ARGELANDER'S *Uranometry*, in which this star is wanting. He estimated it as 4.5, it being much easier seen than *i Virginis*, the reddish yellow star south of *α Virginis*. It should be noted that *i Virginis* itself has been suspected of variability by SECCHI.

As the star is missing in the best charts, SCHMIDT suspected variability. His later observations confirmed this suspicion, the star slowly decreasing until June 19, 1866, although it was then still visible to the naked eye in the moonlight. PIAZZI, 8; LALANDE, 6½ (*A.N.* LXVII, 204). The star is clearly recorded and described by SUFI (*Nature* XII, 188). It is No. 19 of *Virgo* in SUFI'S list, and is given as 5-6. BURNHAM has discovered that the star is really a very close double, the components being 6.2 and 6.5, distance 0″.48, position-angle 80°.4 (*Sci. Obs.* II, 83; *Nature* XX, 248). The star is PIAZZI XIII, 126, and the magnitudes observed by him are 7 and 6½, and not 8, as given in his Catalogue (SCHÖNFELD'S *Zweiter Cat.*, Introd., p. 4); BRISBANE, 6; HEIS, 6½. The observations at Cordoba vary from 5.7 in 1871 to 6.3 in 1873, fully confirming the variability, so that the star will probably be designated as *Y Virginis* (*U.A.* p. 319).

I have 20 observations of this star, made as follows: 1882, 7; 1883, 8; 1884, 1; 1886 and 1888, 2 each. The extreme

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range is only from 6.0 to 6.3. This is a difficult star to observe, the comparison-stars being unfavorably situated, notwithstanding which, my observations are quite accordant, the range being too slight to give evidence of variation, at least, during the past few years.

21. 230 (*U.A.*) *Virginis:* $14^h\ 10^m\ 2^s$, $-2°\ 36'.8$.

Not in any Catalogue, except WEISSE's BESSEL, 7; ARGELANDER and HEIS, 6; Albany, 6.0. At Cordoba, seen by two observers as 6.6 in 1871 and 1872, and in 1874 as 6.4; since then as 6.3 (*U.A.* p. 320).

My 9 observations were made in the years 1882, 1886, 1887 and 1888. The extreme range is from 6.1 to 6.6, and is great enough to furnish some evidence of fluctuation, and it will repay further watching.

22. 239 (*U.A.*) *Virginis:* $14^h\ 13^m\ 18^s$, $+0°\ 57'.7$.

The Cordoba estimates give 6.5 in 1871, and 6.6 in 1872. So faint an object would not have been visible at Albany; but the observations there made give 5.9. *U.N.* and HEIS both have 6; DM., 6.3; BESSEL, 6½; LAMONT, 6 (*U.A.* p. 320).

The extreme range of my 7 observations made in 1882, 1886 and 1888, is from 6.2 to 6.45, which is too slight to furnish sufficient evidence of change.

23. 375 (*U.A.*) *Hydrae:* $14^h\ 15^m\ 54^s$, $-27°\ 10'.7$.

GOULD thinks this star has manifestly grown brighter in recent years. LACAILLE, 6; LALANDE, 6 and 5½; PIAZZI, 6; ARGELANDER, 5.6; JOHNSON, in 1856, 5.6; HEIS, 6; BEHRMANN, 6.5; YARNALL, in 1854, 5.2. The Cordoba observations give 5.0 (*U.A.* p. 303); HOUZEAU, 5.6.

Of my 6 observations, from 1884 to 1888, 5 are quite accordant 5.0 to 5.15. One observation in 1886 gives 5.5; but an observation in the same month gives 5.1. These observations furnish no evidence of change, certainly during the last five years.

24. 379 (*U.A.*) *Hydrae:* $14^h\ 20^m\ 51^s$, $-28°\ 55'.7$.

This star was found brighter at Cordoba than its magnitude is given in any of the catalogues, none of the estimates placing it below 4.8. Recorded by LACAILLE as 5 in the zone, 6 in his Catalogue. ARGELANDER and HEIS, 5⅔; YARNALL, 5.8; BEHRMANN, 5.6 (*U.A.* p. 303); HOUZEAU, 5.6.

This is a bright star, and consequently difficult to observe. My observations made in the years 1884, 1886 and 1888, apparently show a slight tendency to a progressive diminution of light. One observation in 1884 made the star 4.6. Two estimations in 1886 give 4.65 and 4.7; while 4 observations in 1888 give 5.1, 4.9, 4.9 and 4.95; the extreme range being from 4.6 to 5.1. This star will bear further watching.

25. 246 (*U.A.*) *Virginis:* $14^h\ 21^m\ 46^s$, $-1°\ 40'.0$

At Cordoba it was estimated as 5.4, accordantly, by different observers in 1871 and 1872. Yet at Albany the estimates were 4.8; LALANDE, 4½; PIAZZI, 5; BESSEL, 6; ARGELANDER and HEIS, 5; DM., 5.0. Subsequently observed as 4.8 at Cordoba (*U.A.* p. 321).

Of my 9 observations, made from 1882 to 1888, 8 give a range only from 5.15 to 5.35. One estimate in 1882 made the star 5.6. Evidence of change slight.

26. 36 (*U.A.*) *Scorpii:* $16^h\ 4^m\ 33^s$, $-28°\ 5'.4$.

Eight Cordoba estimates are all within the limits 6.0 and 6.3, but the star is not in HEIS. It is marked "variable?" in Catalogue of *U.A*; LACAILLE and PIAZZI, 6; ARGELANDER, twice as 7; YARNALL, 6; ELLERY, 6 and 7 (*U.A.* p. 284).

A colored star, and somewhat difficult to observe. My 7 observations in the years 1882, and 1886 to 1888, range from 5.9 to 6.3, the range in 1888 alone being from 5.9 to 6.2. Evidence of change, however, considered slight.

27. 204 (*U.A.*) *Sagittarii:* $19^h\ 28^m\ 26^s$, $-24°\ 59'.4$.

GOULD says this star is variable by a considerable amount. Very numerous estimates vary from 5.3 to 6.7, and he thinks the extremes are still wider apart. LACAILLE, LALANDE and PIAZZI give 6; ARGELANDER's zones, 6; not in *U.N.*; HEIS, 4⅔; BEHRMANN, 6.5; YARNALL, 6.0 (*U.A.* p. 291).

This is a very difficult star to observe, as it lies close to a bright one; yet my 7 observations, made in the years 1882 to 1888, are quite accordant, ranging only from 5.9 to 6.1, and furnishing no evidence of change.

28. 265 (*U.A.*) *Sagittarii:* $19^h\ 54^m\ 58^s$, $-28°\ 3'.3$.

Suspected of variability at Cordoba at an early date, and a series of sequences in 1871 seemed to justify the suspicion, and indicate a fluctuation from 4.6 to 5.3; but as they imply a nearly equal variation in the comparison-stars ω and b, GOULD is uncertain how far these inferences may be due to errors of observation (*U.A.* p. 291).

My observations of this difficult star number 25, and extend from 1882 June 6 to 1888 September 26. They apparently show a fluctuation from 4.4 to 5.25. But the extreme limits occur in estimations made only three nights apart in 1886. All the other observations are fairly accordant, lying between 4.75 to 5.1; the mean of all the observations being 4.8. GOULD, 4.7.

29. 5 (*U.A.*) *Capricorni:* $20^h\ 7^m\ 28^s$, $-27°\ 24'.2$.

Cordoba estimates from 6.0 to 6.3; LALANDE, PIAZZI, *U.N.*, and HEIS, 6. ARGELANDER, in the zones, 6 and 4½; and in *B.B.* VI, three times as 5.0, once each as 5.2, 5.8, and 6.0. Second RADCLIFFE Catalogue, 6.1; YARNALL, 6.2; BEHRMANN, 5⅔ (*U.A.* p. 308); HOUZEAU, 6.

My 9 comparisons of this star range from 5.85 to 6.2. If we discard the first (5.85) made in 1882, the other eight

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estimations are quite accordant 6.0 to 6.2, and the constancy of its light appears fairly shown. Star red.

30. 120 (*U.A.*) *Aquarii:* $22^h\ 5^m\ 41^s$, —14° 48′.5.

Cordoba estimates range from 6.1 to 6.6, and GOULD thinks it is probably variable. PIAZZI and BESSEL, 7; LALANDE, 6½ and 6; ARGELANDER, in his zones, 6½; YARNALL, 5; HEIS, 6⅓ (*U.A.* p. 310).

My 6 observations are: 1882 October 9, 6.2; 1886 October 19, November 24, and December 17, 6.5, 6.2 and 6.3; 1887 October 15, and 1888 September 29, 6 1 and 6.3. With the exception of the observation of 1886 October 19 (6.5), the others are quite accordant, ranging only from 6.1 to 6.3, and variability seems very doubtful.

31. 131 (*U.A.*) *Aquarii:* $22^h\ 10^m\ 35^s$, —6° 0′.6.

LALANDE, 5; *U.N.* and HEIS, 5⅓ (a misprint in *U.A.* for 5⅔); BESSEL, 7; YARNALL, 5.5. Cordoba estimates are only 6.4 and 6.5, and the star is marked "variable" in Catalogue (*U.A.* p 310). HOUZEAU, 6; SDM., 6; CHANDLER, 6.

I have six observations, made in the years 1884 to 1888, and the range is only from 6.15 to 6.25, and variability seems very doubtful.

32. 221 (*U.A.*) *Aquarii:* $23^h\ 11^m\ 8^s$, —12° 23′.7.

Although the *U.N.* gives this as 6, SCHMIDT in 1869 found it invisible, or scarcely visible, to the naked eye, and five or six grades fainter than 94 or 97 *Aquarii*, hence 7. He is certain that in 1864 it was equal to 94 *Aquarii* (*A.N.* LXXIV, 286). The Cordoba determinations in 1872 and 1874 agree in giving 6.6. A meridian observation gave 7, which is also BESSEL's value (*U.A.* p. 310). SCHMIDT and GOULD agree that, if it were as faint as when their observations were made, it could not have been seen with the naked eye at Bonn.

Of my 6 observations made in the years 1884, 1886, and 1887, only one is very discordant 6.7, the others ranging from 6.3 to 6.55. Evidence of change slight.

33. 223 (*U.A.*) *Aquarii:* $23^h\ 12^m\ 27^s$, —10° 17′.6.

SCHMIDT in 1870 stated that this star had for many years appeared variable to him, and that the period is very long (*A.N.* LXXVII, 118). Three observations at Cordoba, in different years, give the same value, 4.8. LALANDE, 6; PIAZZI, 5; BESSEL, 5⅓; *U.N.* and HEIS, 5; JOHNSON, 5.4 (*U.A.* p. 310). GORE found it brighter than χ *Aquarii* in December, 1875 (*S.S. Objects*, p. 114). HOUZEAU, 5; STONE, 5.

I have 6 estimates of this bright star, made in the years 1882, 1886 and 1887, the extreme range being from 4.4 to 4.75, and the evidence of variability appears slight.

ON AN IMPROVEMENT IN THE COMPUTATION OF AN ORBIT,

BY REV. G. M. SEARLE.

The method of computing an orbit given in No. 162 of this Journal, though reasonably simple and compact in form, labors under the disadvantage of a somewhat slow convergence of the hypotheses. It is true that after three have been made, the fourth can be formed on their results, after the method given by GAUSS; but even this, as shown by him in a practical example, cannot be depended on as absolutely correct, when the intervals of time are considerable. It is then of course desirable in any method to obtain as great convergence as possible.

It will be seen that the value of b^{-2}, deduced from the positions of the intersections of the three lines of observation with an approximate plane of the orbit, nevertheless cannot be considered as a close approximation to the true value. If the value of ν has been taken correctly, that of b^{-2}, if it differs from the one resulting from the values of a and p found from the hypothesis, is indeed a certain sign of incorrectness in the value of a^{-1} assumed for that hypothesis. But if a new hypothesis is made, based on this deduced value of b^{-2}, it is clear that the position of the plane of the orbit will be thereby changed, so that the intersections will now give a somewhat different result.

It is indeed probable that this new result will be a further step in the same direction; for since the first and third geocentric distances are increased or diminished proportionately (if the value of ν remains about the same), the orbit will either recede from or approach that of the earth. The eccentricity of the orbit, then, both as deduced from the time with the first and third radii vectores, and from the position and length of the three radii irrespective of time, will be likely to increase in the first case, and in the second to tend toward the very small value which it has in the case of the earth itself. But if the rates of change of the two eccentricities should be about equal, it is plain that a good many steps would probably be taken before they could be made to coincide. It seems likely, as a rule, that the one deduced from the time will change most rapidly.

We can, however, at the end of any hypothesis, decide this point in the special case. For we may take the quantities resulting, for instance, from a parabolic hypothesis, and compute from them the value of b^{-2} from the intersections; that resulting from r, r'', f' and t''—t, will of course be zero in this case. The value resulting from the intersections we will denote by B_i; the other by B_t. We may then take those

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similarly deduced from the values of r, or r'', etc., furnished by some other assumption for u used during the trial; for an elliptic result for B_t it is of course necessary that

$$(r+r''+\kappa)^{\frac{3}{2}} - (r+r''-\kappa)^{\frac{3}{2}} < 6k(t''-t)$$

By interpolation we may then ascertain where the values of B_ι and B_t will coincide.

The value of B_ι is obtained in this process for the new value of u by computing l, m, h, η and x by the method of GAUSS or some similar one; if we use GAUSS's method, since the chord is given, we shall save time by computing l and m by means of the angle whose sine is $\frac{\kappa}{r+r''}$, and which seems most significantly denoted by χ. Using this, we have

$$l = \sin^2 \tfrac{1}{2}\chi \sec\chi \; ; \qquad m = k^2(t''-t)^2 \, (r+r'')^{-3} \sec^3\chi$$

Having obtained x, we compute $\sin^2 g'$ from it; then of course have

$$B_\iota = \frac{\sin^2 g'}{r r'' \sin^2 f'},$$

This process, tried at the end of the second parabolic hypothesis for OLBERS's comet, from places of August 28, September 21, and October 19, embracing a heliocentric motion of about 52°, gives for the parabolic result,

$$B_\iota = +0.01683 \qquad B_t = 0$$

For another value of u, we find:

$$B_\iota = +0.02965 \qquad B_t = +0.03966$$

For the first, then, $B_\iota - B_t = +0.01683$.
For the second it $= -0.01001$.

This gives a coincidence at $B_\iota = B_t = +0.02487$; which again gives, using the corresponding value for p, a period for the comet of 72.25 years.

But this is not all. By the material thus furnished we may also compute a more accurate value of ν for the next hypothesis.

In the first place we will substitute a more convenient way of computing η and η'' when κ, the chord, is known; which can also be introduced at the end of any hypothesis. We have

$$\frac{1}{p} = \frac{r+r''-\sqrt{2rr''}\cos f'}{2rr''\sin^2 f'} + 2x' \cdot \frac{\cos f'}{\sqrt{rr''}\sin^2 f'}$$

in which $x' = \sin^2 \frac{1}{2} g'$.

The first of these terms, putting $r+r'' = \kappa \operatorname{cosec}\chi$, and $2\sqrt{rr''}\cos f = \kappa \operatorname{cotg.}\chi$, becomes

$$\frac{\kappa \tan \frac{1}{2}\chi}{2rr''\sin^2 f'}$$

The second, putting for $2x'$,

$$\frac{\sin^2 g'}{2\cos^2\frac{1}{2}g'} = \frac{b^{-2} rr'' \sin^2 f'}{2\cos^2 \frac{1}{2} g'},$$

becomes

$$\frac{b^{-2}\sqrt{rr''}\cos f'}{2(1-x')}$$

We have then $$\frac{2}{p} = \frac{\kappa \tan\frac{1}{2}\chi}{rr''\sin^2 f'} + \frac{b^{-2}\sqrt{rr''}\cos f'}{(1-x')}$$

For very eccentric orbits, x' can be neglected in this formula, but can of course be computed by $\sin^2 g' = b^{-2} rr'' \sin^2 f'$. In the present case x' has been obtained in computing B_ι; but as we need it here for B_t, it should be got, if at all, by $\sin^2 g' = B_t rr'' \sin^2 f'$.

We have then $$\eta = 1 + \frac{2}{p} \cdot \frac{\sqrt{r'}}{3} \cdot \frac{\sqrt{r''}\sin f \tan f}{1-\frac{6}{5}(x-\xi)}$$

$$\eta'' = 1 + \frac{2}{p} \cdot \frac{\sqrt{r'}}{3} \cdot \frac{\sqrt{r}\sin f'' \tan f''}{1-\frac{6}{5}(x''-\xi'')}$$

in which x and x'' are obtained by

$$\sin^2 g = B_t \, r'r'' \sin^2 f \qquad \sin^2 g'' = B_t \, rr' \sin^2 f''$$

This process gives us, in our present case, for the parabolic value of u,

$$\log \frac{\eta''}{\eta} = 9.996481,$$

and for the elliptic value of u,

$$\log \frac{\eta''}{\eta} = 9.996332.$$

Interpolating for the true value of B_t, we have

$$\log \frac{\eta''}{\eta} = 9.996388 \qquad \log \left[\nu = \frac{\eta''}{\eta} \frac{(t''-t')}{(t'-t)} \right] = 0.055905$$

which agrees with the true value to one decimal, in the last place. No further hypothesis would be required.

It may be remarked, that it is not necessary to proceed to the exact solution of the hypothesis to which this process is to be applied. It is enough, if we have two values of u not very far from the truth; but of course this involves the additional labor of obtaining g' for both of them, instead of having it furnished for one by the solution of the hypothesis, while it saves the labor of completing it.

It may also be remarked, that it will probably be well to correct the value of $\frac{n''}{n}$ derived from the first hypothesis, if our second is to be formed without a new value of b^{-2}, by at least recomputing ϑ, f and f'' by the resulting value of ν, and with these values of f and f'' obtaining η, η'' and ν again. The former value of r' will be accurate enough. But we may often apply the process described above to the first hypothesis itself.

It may, perhaps, be doubted whether B_ι and B_t can be supposed to change uniformly for changes in u; if not, the process of interpolation for them cannot be depended on. But B_ι is evidently about proportional to

$$x = \frac{m^2}{\eta^2} - l$$

and the differentiation of this equation and of that for h gives (neglecting ξ)

$$[1+3(\eta-1)+\tfrac{6}{5}(\eta-1)^2]\, dx = \frac{2d\,[m^2]}{\eta} - \tfrac{6}{5}\,(\eta-1)^2\, dl$$

showing that dx will be as uniform as $d(rr''\cos f')^{-3}$

We may also differentiate $B_t = SS'' - \frac{1}{4} S_0^2$. This gives

$$2\, dB_t = (S'+S''-S)\, dS + (S'+S-S'')\, dS'' - S_0\, dS'$$

which shows that no sudden changes can occur in it unless f or f'' were very small, in which case no method can be used with accuracy.

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OBSERVATIONS OF COMET 1888 *a* (*SAWERTHAL*),

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY,

BY O. C. WENDELL, ASSISTANT.

[Communicated by Professor EDWARD C. PICKERING, Director.]

1888 Greenwich M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Mar. 23 21 57 48	1	5 , 5	—5 47.29	— 9 15.6	21 35 55.99	— 6 35 28.6	*n*9.595	0.795
April 6 21 1 30	2	6 , 6	—0 4.45	— 3 10.5	22 19 4.04	+ 9 11 11.4	*n*9.630	0.747
16 20 54 0	3	5 , 5	—2 15.67	+ 7 55.7	22 47 47.37	17 43 43.5	*n*9.643	0.708
24 20 39 51	4	5 , 5	—0 46.04	— 0 35.8	23 9 3.86	23 14 48.1	*n*9.661	0.678
June 29 15 31 59	5	6 , 6	—0 28.28	+11 34.8	1 0 26.20	47 38 43.7	*n*9.770	0.780
July 5 15 0 48	6	5 , 5	—0 50.55	— 3 51.4	1 4 14.87	+48 57 38.2	*n*9.771	0.791

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 41 44.44	—1.16	— 6 26 8.2	— 4.8	B.B. VI, Supplement
2	22 19 9.42	—0.93	+ 9 14 30.0	— 8.1	Weisse's Bessel 22ʰ, 368
3	22 50 3.87	—0.83	17 35 57.5	— 9.7	B.B. VI, 4833
4	23 9 50.64	—0.74	23 15 34.6	—10.7	Weisse's Bessel 23ʰ, 154-5
5	1 0 53.64	+0.84	47 27 20.3	—11.4	Oe. Arg. 1111
6	1 5 4.34	+1.08	+49 1 40.7	—11.1	Oe. Arg. 1195

THE FAINTER VARIABLES,

BY HENRY M. PARKHURST.

Of the variable stars included in the list in No. 183, I have observed all but eleven, with an aperture of nine inches. From these observations I select such notes in relation to the minima as may be serviceable. When a star is low in the heavens during the minimum, it may disappear at much above 14^M. The duration of the invisibility will furnish some guide to the best time of observation with any larger aperture. But in most cases, the variable was either invisible when first looked for, or was lost in the twilight before it reappeared.

112 Invisible more than a month.
114 Could not see it in November 1885; a month later, bright.
432 Remains invisible about nine months.
466 Invisible for several months.
513 Disappears for a month or more.
715 Invisible at least four months.
845 Did not disappear; min. about 1887 February 8.
1222 Did not disappear.
1577 The variable disappears entirely for about two months, but there is a small star near it which has probably been mistaken for it in fixing the magnitude at the minimum.
1582 Unless wrongly identified, I saw it easily for four or five months.
1717 Disappears for about a month.
2478 Disappears entirely for a month or more.
2528 Does not always disappear at minimum.
2742 Disappeared for two months or more.
2780 Disappeared for two months or more.
2976 Does not disappear. Minima in 1885 about March 28 and December 19.
3477 Does not disappear.
3890 Always easily seen during my observations.
4315 Invisible for six months or more, until jnst before conjunction with the sun.
4816 Invisible for a month or more.
5070 Invisible for a month or more.
5494 Always easily seen during my observations.
5501 Invisible for two months or more.
5677 Seen with difficulty at the minimum.
5770 Invisible for a month or more.
5795 Invisible for two months or more.
5830 Invisible for a month or more.
5831 Invisible for a month or more.
6905 Does not disappear.
6921 Invisible for two months or more.
7045 For four months seen only by glimpses.
7220 Only visible for about four months.
7252 Only visible for two months.
7455 Invisible for five months or more.
7571 Visible only from about two months before to three months after the maximum.
7577 Invisible for three months or more.
7944 Invisible for three months or more.
8153 Invisible for four months or more.

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EPHEMERIS OF COMET 1888 *e* (*BARNARD*),

BY LEWIS BOSS.

[Continued from No. 182.]

1888 Gr. M.T.	App. α h m s	App. δ ° ′	log r	log Δ	Light
Nov. 17.5	3 50 48	—2 29.5	0.31081	0.0399	11.7
18.5	3 43 54	2 49.7	0.30960	0.0380	
19.5	3 36 58	3 9.4	0.30840	0.0367	
20.5	3 29 59	3 28.8	0.30721	0.0358	
21.5	3 22 59	3 47.7	0.30603	0.0355	12.2
22.5	3 15 59	4 6.1	0.30486	0.0356	
23.5	3 9 0	4 23.9	0.30369	0.0362	
24.5	3 2 3	4 41.0	0.30254	0.0373	
25.5	2 55 9	4 57.4	0.30139	0.0389	12.3
26.5	2 48 19	5 13.0	0.30026	0.0409	
27.5	2 41 34	5 27.9	0.29913	0.0434	
28.5	2 34 56	5 41 9	0.29801	0.0464	
29.5	2 28 23	5 55.0	0.29691	0.0497	11.9
30.5	2 21 59	6 7.3	0.29582	0.0534	
Dec. 1.5	2 15 42	6 18.7	0.29474	0.0575	
2.5	2 9 35	6 29.3	0.29367	0.0619	
3.5	2 3 36	6 39.0	0.29261	0.0667	11.3
4.5	1 57 47	—6 47.9	0.29156	0.0717	
Dec. 5.5	1 52 8	—6 56.0	0.29053	0.0769	
6.5	1 46 39	7 3.3	0.28950	0.0824	
7.5	1 41 20	7 9.8	0.28849	0.0881	10.4
8.5	1 36 12	7 15.6	0.28749	0.0940	
9.5	1 31 14	7 20.7	0.28651	0.1000	
10.5	1 26 26	7 25.2	0.28554	0.1061	
11.5	1 21 49	7 29.0	0.28459	0.1124	9.5
12.5	1 17 21	7 32.2	0.28365	0.1188	
13.5	1 13 4	7 34.9	0.28272	0.1253	
14.5	1 8 56	7 37.1	0.28179	0.1318	
15.5	1 4 58	7 38.7	0.28090	0.1383	8.5
16.5	1 1 9	7 39.9	0.28003	0.1449	
17.5	0 57 29	7 40.7	0.27815	0.1515	
18.5	0 53 58	7 41.0	0.27730	0.1581	
19.5	0 50 36	—7 41.0	0.27746	0.1646	7.7

Observations on October 18 show no appreciable correction to the ephemeris of this comet contained in No. 182, of which the above is a continuation.

NEW ASTEROIDS.

A planet of the 13th magnitude, or fainter, was discovered by PALISA at Vienna, Oct. 25, in the following position:

1888 Oct. 25.2486 Gr. M.T. $\alpha = 13° 24' 6''$ $\delta = +2° 54' 58''$

The asteroid discovered by BORRELLY, May 12 (*A.J.* VIII, 32), proved to be no. 116, *Sirona*. Consequently, that found by PALISA, May 16, became no. 278; and this one is no. 279. Names have been assigned, as follows, to some of those recently discovered.

(272) *Antonia*. (274) *Philagoria*. (275) *Sapientia*. (276) *Adelhéid*. (278) *Paulina*.

Another, of the 12th magnitude, was discovered by PALISA, Oct. 31, in the position,

1888 Oct. 31.5165 Gr. M.T. $\alpha = 2^h 2^m 46^s.2$ $\delta = +13° 34' 29''$

This is no. 280.

NEW COMET, 1888 *f* (*BARNARD*, *Oct. 30*).

A despatch received from Professor E. S. HOLDEN, Oct. 31, announces the discovery of a new comet by Professor E. E. BARNARD, at the Lick Observatory, in the following position:

1888 Oct. 31.0399 Gr. M.T. $9^h 43^m 22^s.2$ $-15° 18' 52''$ Daily motion in R.A., $+1^m 32^s$; in Decl. $+9'$.

Its physical appearance is as follows: Slightly elongated; 1′ in diameter; 11^M or fainter; strong central condensation.

An observation by Mr. TUTTLE has been telegraphed by the Superintendent of the Washington Observatory:

1888 Nov. 1.8612 Gr. M.T. $\alpha = 9^h 46^m 14^s.3$ $\delta = -15° 1' 37''$

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ORBIT AND PROPER MOTION OF 85 *PEGASI* (β 733),

BY J. M. SCHAEBERLE, ASTRONOMER OF THE LICK OBSERVATORY.

[Communicated by the Director.]

The duplicity of 85 *Pegasi* was discovered by Mr. BURNHAM with the Chicago telescope in 1878.

As he has recently obtained another series of measures of this difficult double, with our great refractor, it seemed worth while, even with the scanty data at hand, to compute an approximate orbit of this interesting binary. Mr. BURNHAM has furnished me with the following data:

A AND *B*

Date	P	D	Observer
	°	″	
1878.73	274.0	0.67	β 3 nights
1879.46	284.6	0.75	β 5 "
1880.59	298.3	0.65	β 5 "
1881 54	311.5	0.58	β 1 "
1883.75	333 ±	very close	β 1 " (rough)
1888.69	126.7	0.95	β 5 "

A combination of the graphical and analytical* methods gave various orbits, in all of which, from the nature of the case, the residuals in the position-angles were rather large. The orbit given below was obtained by interpolation from a series of orbits in which T, ϵ, i and *Period* were varied.

ELEMENTS OF 85 *Pegasi* (β 733.)

$$T = 1884.00$$
$$\pi - \Omega = 70°.3$$
$$\Omega = 306°.1$$
$$i = 68°.6$$
$$\epsilon = 0.35$$
$$a = 0''.96$$
$$\text{Period} = 22.3 \text{ years}$$

This orbit represents the above observations, as follows:

O—C

ΔP	ΔD
°	″
—6.3	+0.06
—2.6	+0.08
+1.7	—0.06
+7.2	—0.10
—7.2	-
—1.6	+0.04

A general idea of the apparent relative positions of the components during one revolution can be obtained from the following ephemeris:

A AND *B*

Date	P	D
	°	″
1876.0	235.9	0.47
1880.0	291.8	0.78
1884.0	351.7	0.19
1888.0	124.5	0.93
1892.0	145.0	0.94
1896.0	172.7	0.81

To determine the relative proper-motion of 85 *Pegasi* from the observed position-angles and distances of the star *C*, I have used the following data:

A AND *C*

Date	P	D	Observer
	°	″	
1870.00	77.0	16.00	Brünnow
1877.94	49.8	14.0	Flammarion
1878.54	33.6	14.40	β
1879.27	30.4	14.96	β
1880.57	25.0	15.41	β
1881.54	20.8	16.29	β
1882.77	17.1	17.34	β
1888.67	0.9	21.71	β

A solution by the method of least-squares gives for the

* On page 407 of KLINKERFUES's *Theoretische Astronomie*, the 4th equation should read, $\rho \sin p = r \cos i \sin(v + \pi - \Omega)$.

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velocity and direction of motion of 85 *Pegasi*, regarding C as fixed,

Annual motion $= 1''.305$
Direction of motion $= 140° 20'.4$

The proper motions in R.A. and Decl. are accordingly, $\Delta\alpha = +0''.833$, $\Delta\delta = -1''.005$, These numbers differ somewhat from those given by ARGELANDER, MAEDLER and BRÜNNOW, as can be seen from the following results taken from the *Vierteljahresschrift der Astr. Gesellsch.*, IX Jahrg., p. 39.

	ARGELANDER	MAEDLER	BRÜNNOW
	$''$	$''$	$''$
$\Delta\alpha$	+0.981	+1.001	+0.911
$\Delta\delta$	−0.985	−0.944	−0.869

As Professor BRÜNNOW suggests, the cause of these differences may be due to a slight proper-motion of the small star C.

If we assume the parallax of 85 *Pegasi* to be $0''.054$ as found by BRÜNNOW, the combined mass of the system is, according to the above elements, 11.3 times the sun's mass.

Mt. Hamilton, 1888 *October* 17.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *c* (*BROOKS*),

MADE AT THE DUDLEY OBSERVATORY,

BY LEWIS BOSS.

1888 Albany M.T.	∗	No. Comp.	☄ — ∗ $\Delta\alpha$	☄ — ∗ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s			m s	′ ″	h m s	° ′ ″	s	″
Sept. 14 8 38 33	8	15 , 5	−1 14.07	−1 46.4	14 27 18.14	+26 35 32.0	9.686	0.716
24 8 16 13	9	15 , 5	+2 23.33	−4 29.9	15 8 38.33	+18 57 3.9	9.657	0.726

Mean Places for 1888.0 of Comparison-Stars.

∗	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
8	14 28 32.22	−0.01	+26 37 9.5	+8.9	DM.26° 2577, comp. with W. Bess. 428-9
9	15 6 14.88	+0.12	+19 1 25.0	+8.8	Weisse's Bessel 85

NOTES. — Sept. 14. Observations difficult on account of moonlight.—Probable error of $\Delta\alpha$, $\pm 0^s.20$; of $\Delta\delta$, $\pm 0''.7$—The comparison-star is of the 10th magnitude, and is the north preceding and brighter of the two stars which constitute DM. 26° 2577.— The measured difference from Weisse 428-9 is: $\Delta\alpha = +7^m\ 1^s.75$; $\Delta\delta = -5'\ 23''.6$; corrected for refraction. — Sept. 24. Observations not difficult.

ON SOME REMARKABLE ANOMALIES IN THE PERIOD OF *Y CYGNI*,

BY S. C. CHANDLER.

I desire to direct attention to the curious phenomena which this variable is exhibiting, and to make an urgent appeal, especially to the astronomers of northern Europe, — where alone, for many months to come, observations can be effectively carried on — for determinations of minima. The period appears to be subject to enormous inequalities for which we have no analogue among other variables of this type. These inequalities develop so rapidly as to become sensible in the course of a few weeks' observations, and are of such magnitude as to render futile the attempt to predict the minima, even but a few months in advance, until their character is more certainly established.

The elements on page 150, Vol. VII, of this Journal, were found from two normal epochs, formed from groups of a few weeks' observations each, the first extending from 1886 Dec. 9, to 1887 Jan. 11, and the second from 1887 Sept. 18 to Nov. 5. From the sharpness with which the minima were determined, the resulting period was considered to be accurate within a couple of seconds, as I stated in the place quoted. It was with a good deal of astonishment, therefore, when, in the spring of 1888, the star got enough above the eastern horizon to be observed, that I found it at its maximum brilliancy at the time of predicted minimum, and that no fluctuation was perceptible even when the watch was prolonged beyond the time at which, by every reasonable probability, the maximum brightness should have been attained. After several attempts, the minima were reestablished, but the correction to the elements implied by these observations was four or five hours. Subsequently the difference increased, until it reached nearly seven hours in October, since which time observations have been no longer practicable.

From the data available when my catalogue was prepared, I could form no clear idea of the true nature of the deviations from uniformity of period, and the fact of the existence of

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irregularity was therefore simply stated; the old period being retained, but a new epoch provisionally substituted.

In order that the nature of the anomalies may be further investigated, I give below all the minima which are at present suitable for use. The table contains thirteen minima observed by me, marked C; three minima by Mr. P. S. Yendell, observed this summer, and kindly communicated in manuscript, marked Y; and five dates of minima which I have inferred from the observations published by Mr. Sawyer, and marked S. To these last, resting on isolated comparisons, must of course be assigned less weight than to regular determinations, but their evidence is too valuable to be entirely neglected.

Besides the above complete minima, I have several other incomplete ones, which can be utilized at some future date.

Table of Observed Minima.

Epoch	Observed Minimum Camb. M.T.	Red. to ☉	Observed Minimum Heliocentric Gr. M.T.	Wt.	Obs.	O—C	O—C′
	d h m	m	d h m			m	m
0	1886 Dec. 9 6 15	—2.0	1886 Dec. 9 10 57.5	½	C	— 17.0	—38.5
8	21 6 12	—3.0	21 10 53.5	1	C	+ 4.6	— 9.6
12	27 6 0	—3.5	27 10 41.0	1	C	+ 4.9	— 5.8
16	1887 Jan. 2 5 54	—3.9	Jan. 2 10 34.6	2	C	+ 11.3	+ 4.0
22	11 5 34	—4.4	11 10 14.1	1	C	+ 10.0	+ 7.5
165	Aug. 13 8 50	+5.1	1887 Aug. 13 13 39.6	½	S	— 46.9	—20.6
167	16 9 20	+5.2	16 14 9.7	1	S	— 10.4	+15.2
169	19 9 5	+5.2	19 13 54.7	½	S	— 19.0	+ 5.8
173	25 8 25	+5.3	25 13 14.8	1	S	— 46.1	—23.0
183	Sept. 9 8 35	+4.8	Sept. 9 13 24.3	½	S	— 4.6	+13.8
189	18 8 35	+4.6	18 13 24.1	1	C	+ 14.4	+31.6
205	Oct. 12 7 25	+3.1	Oct. 12 12 12.6	3	C	— 5.9	— 0.7
207	15 7 26	+2.9	15 12 13.4	3	C	+ 1.3	+ 5.0
209	18 7 17	+2.7	18 12 4.2	1	C	— 1.5	+ 0.8
217	30 6 48	+1.6	30 11 34.1	1	C	— 6.0	— 9.7
221	Nov. 5 6 44	+1.1	Nov. 5 11 29.6	3	C	+ 2.3	— 4.6
390	1888 July 15 14 24	+4.6	1888 July 15 19 13.1	5	C	+286.6	+27.2
418	Aug. 26 13 0	+5.3	Aug. 26 17 49.8	2	C	+292.9	—30.4
428	Sept. 10 12 50	+4.8	Sept. 10 17 39.3	2	Y	+314.4	—32.2
440	28 12 54	+4.0	28 17 42.5	2	Y	+356.0	—21.9
448	Oct. 10 13 23	+3.3	Oct. 10 18 10.8	2	Y	+409.9	+11.2

The values (O—C) are the deviations from the elements on p. 150, Vol. VII. It is seen at once that the results for different years are utterly incompatible with a uniform period. The hypothesis of further subdivision of the period is also excluded, by other observations.

Dividing the data into five groups, we get the following normals, and from their intervals the periods given in the last column.

E	O—C	Obs.	Period
	m		d h m s
14	+ 6.0	C	
			1 11 56 31.8
171	— 36.3	S	
			57 45.3
209	0.0	C	
			58 19.5
398	+288.4	C	
			58 30.9
439	+358.7	Y	

These results apparently show an increase of the period at a rate entirely beyond precedent. From the three normals based on my own observations alone, I find the elements, referred for convenience to epoch 519,

$$1889\ \text{Jan.}\ 25^{d}\ 5^{h}\ 39^{m}.6\ (\text{Gr. M.T.}) + 1^{d}\ 12^{h}\ 0^{m}\ 0^{s}.12\ (E-519) + 0^{s}.24\ (E-519)^{2}$$

The extraordinary lengthening of the period indicated by these elements, amounting to half a second of time between two successive recurrences, transcends a hundred-fold the rate of change in *Algol's* period when it was shortening most rapidly, and a thousand-fold the corresponding change in the period of *U Ophiuchi*.

It is by no means to be inferred that, in adopting the above form of expression, I am of opinion that a secular change is going on. On the contrary, the evidence points clearly to some form of periodical change, without enabling us yet to determine the constants. In all probability the cycle of its principal term is very short, extending, perhaps, over but one or two hundred periods.

The comparison of the above elements is shown in the last column of the table, (O—C′). It should be observed that the star belongs to the class of *Algol*-variables whose minima can be fixed by observation with great accuracy, the variation of brightness being relatively very rapid. The probable error of a single determination of minimum will not, I think, prove to be greater than $\pm 4^{m}$ or $\pm 5^{m}$. Such observation-errors as those indicated on 1888 July 15 and Aug. 26, for example, are practically impossible, for half an hour

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after or before minimum the star is well on its way to or from maximum. The differences (O—C′) are, therefore, for the most part, real deviations; and the law of the perturbations of the period is manifestly a very complicated one, which, in the shortness of some of its terms, suggests similar anomalies that obscurely appear, but to a far less amount, in *λ Tauri*, where their mathematical expression has never yet been determined, on account of the uncertainty and incompleteness of the observations.

The close commensurability of the present value of the period with the mean solar day enables us to construct an approximate ephemeris in the following convenient form.

Approximate Ephemeris of *Y Cygni*, Greenwich M.T.

Minimum about $5^h\ 40^m$				Minimum about $17^h\ 40^m$			
E = 487	1888 Dec. 8	E = 527	1889 Feb. 6	E = 488	1888 Dec. 9	E = 528	1889 Feb. 7
489	11	529	9	490	12	530	10
491	14	531	12	492	15	532	13
493	17	533	15	494	18	534	16
495	20	535	18	496	21	536	19
497	23	537	21	498	24	538	22
499	26	539	24	500	27	540	25
501	29	543	27	502	30	542	28
503	1889 Jan. 1	543	Mar. 2	504	1889 Jan. 2	544	Mar. 3
505	4	545	5	506	5	546	6
507	7	547	8	508	8	548	9
509	10	549	11	510	11	550	12
511	13	551	14	512	14	552	15
513	16	553	17	514	17	554	18
515	19	555	20	516	20	556	21
517	22	557	23	518	23	558	24
519	25	559	26	520	26	560	27
521	28	561	29	522	29	562	30
523	31	563	Apr. 1	524	Feb. 1	564	Apr. 2
525	Feb. 3			526	4		

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 *e* (*BARNARD*),

MADE AT THE DUDLEY OBSERVATORY,

By LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Oct. 18 12 51 43	8	21 , 7	+0 48.98	+2 5.1	6 10 10.22	+5 56 19.7	*n*9.534	0.741
13 18 9	9	21 , 7	—0 51.77	—2 2.6	6 10 7.32	+5 56 8.4	*n*9.488	0.737
Nov. 1 13 44 23	10	15 , 5	+5 11.75	—2 40.7	5 22 8.89	+2 38 43.3	*n*8.898	0.753
14 20 17	11	15 , 5	—4 39.25	+4 19.3	5 22 2.63	+2 38 17.9	*n*8.314	0.753
15 7 11	12	18 , 6	+2 27.09	—1 25.6	5 21 53.39	+2 37 43.8	8.848	0.753
5 14 21 52	13	9 , 3	+6 19.72	—0 25.8	5 2 34.50	+1 26 19.8	8.640	0.763

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
8	6 9 19.19	+2.05	+5 54 13.0	+1.6	Glasgow 1533
9	6 10 57.05	+2.04	+5 58 9.5	+1.5	Bonn VI, 5° 1164
10	5 16 54.52	+2.62	+2 41 20.3	+3.7	Paris 6200 and Albany 1683
11	5 26 39.30	+2.58	+2 33 55.3	+3.3	Paris 6404 and Albany 1790
12	5 19 23.69	+2.61	+2 39 5.8	+3.6	Albany 1714
13	4 56 12.05	+2.78	+1 26 41.0	+4.6	P.M. 509, Paris 5793 & Alb. 1537

Notes. — Oct. 18. The light of the comet is equivalent to $9^M.0$. — Nov. 1. The coma is faint and large. It appears to be more extended in (approximately) position-angle 0°. The nuclear condensation is very strong. — Nov. 5. Barely visible through light clouds.

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OBSERVATION OF COMET 1888 *f* (BARNARD),

MADE AT THE DUDLEY OBSERVATORY, ALBANY,

BY LEWIS BOSS.

1888 Albany M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
Nov. 1 16h 54m 58s	1	6 , 2	—4m 20s.03	—0′ 41″.7	9h 46m 15s.07	—15° 1′ 32″.8	n9.348	0.859

Mean Place for 1888.0 of Comparison-Star.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	9h 50m 33s.93	+1s.17	—15° 0′ 51″.5	+0″.4	Weisse's Bessel 1054

OBSERVATIONS OF COMETS, ETC.,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

[Communicated by the Superintendent.]

1888 Washington M.T.	*	No. Comp.	☄—* Δα	☄—* δ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
			COMET *a* (SAWERTHAL).						
July 2d 11h 30m 22s.7	1	20 , 4	—0m 48s.71	— 7′ 46″.3	1h 2m 31s.27	+48° 19′ 27″.7	n9.831	0.702	F
			COMET *c* (BROOKS).						
Aug. 11 9 6 8.4	2	14 , 3	—1 4.81	+ 7 20.3	10 38 54.36	+44 48 59.9	9.758	0.791	F
23 8 4 2.8	3	19 , 5	—0 44.43	+ 1 56.2					W
24 8 7 42.1	4	30 , 6	+0 54.19	— 2 4.1	12 19 16.00	+41 18 26.3	9.784	0.559	W
Sept. 2 8 6 30.2	5	38 , 7	—1 25.69	+ 3 46.3	13 20 16.49	+35 48 2.1	9.751	0.608	W
			COMET *e* (BARNARD).						
Sept. 12 15 48 55.1	6	54 , 10	+0 19.60	+11 58.9	6 50 36.58	+10 18 1.9	n9.570	0.671	W
13 15 25 54.2	7	24 , 5	—6 12.06	— 1 11.7					T
19 15 32 11.5	8	20 , 5	—0 55.00	+ 4 38.3	6 47 51.40	+ 9 43 2.7	n9.548	0.671	W
16 9 22.8	9	22 , 5	—1 13.25	— 4 38.9	6 47 50.49	+ 9 42 45.8	n9.476	0.658	W
29 15 4 34.3	10	20 , 4	—6 1.63	+15 54.1	6 40 50.17	+ 9 3 52.6	n9.532	0.674	T
Oct. 2 15 44 31.4	11	30 , 6	—3 2.92	— 7 45 3	6 37 33.29	+ 8 21 7.2	n9.608	0.697	T
3 14 46 0.3	12	20 , 4	—4 48.78	+ 4 34.5	6 36 27.59	+ 8 13 59,6	n9.510	0.678	T
4 16 9 30.0	12	20 , 4	—6 5.93	— 3 26.9	6 35 10.46	+ 8 5 58.2	n9.240	0.677	T
6 16 58 48.2	13	10 , 2	+3 45.04	+ 6 6.9					T
8 14 14 51.3	14	25 , 5	+1 17.48	+ 0 37.8	6 28 10.06	+ 7 25 29.7	n9.516	0.688	T
12 14 45 22.9	15	20 , 4	—2 50.63	+ 6 1.6	6 22 55.80	+ 6 57 56.2	n9.612	0.707	T
13 13 49 48.0	15	25 , 5	—4 41.10	— 3 19.2	6 21 5.35	+ 6 48 35.4	n9.512	0.691	T
17 16 34 33.2	16	20 , 4	+2 29.49	— 0 17.8	6 12 11.51	+ 6 5 46.5	8.369	0.678	T
17 24 39.4	17	20 , 4	+0 54.14	— 1 59.5	6 12 6.60	+ 6 5 18.1	9.091	0.690	W
28 14 14 31.4	18	30 , 6	+3 9.78	— 0 0.3	5 42 1.19	+ 3 46 58.3	9.042	0.705	T
30 15 0 44.6	19	20 , 4	+5 10.40	— 1 12.8	5 30 34.87	+ 3 11 8.6	8.320	0.710	T
			COMET *f* (BARNARD).						
Nov. 1 15 31 54.2	20	9 , 2	—4 20.77	— 0 47.0	9 46 14.35	—15 1 37.0	n9.571	0.809	T
11 15 15 37.7	21	15 , 3	+7 3.13	+ 4 24.7	10 0 9.48	—13 20 0.4	n9.554	0.807	T
20 17 33 13.6	22	10 , 2	+1 12.26	— 0 15.5	10 10 39.10	—11 27 40.7	n8.784	0.831	F
17 35 40.8	23	5 , 1	—1 35.80	+ 3 32.1	10 10 39.66	—11 27 44.9			F
21 17 39 48.1	24	19 , 5	+1 57.24	+ 0 1.7	10 11 41.69	—11 14 4.0	n8.699	0.831	F
			OBSERVATION OF ASTEROID (280).						
Nov. 3 10 25 59.4	25	10 , 2	—0 56.98	— 2 31.0	1 59 25.04	+13 31 36.8	n8.889	0.578	F

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Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 3 19.02	+0.96	+48 27 25.3	—11.3	Oe. Arg. 1155
2	10 39 59.95	—0.78	+44 41 35.6	+ 4.0	Radcliffe 2554
3					DM. +41° 2285
4	12 18 22.36	—0.55	+41 20 24.8	+ 5.6	Weisse's Bessel 346
5	13 21 42.43	—0.25	+35 44 8.1	+ 7.7	Weisse's Bessel 410
6	6 50 16.16	+0.82	+10 6 3.6	— 0.6	Bonn VI 1335
7					DM. +10° 1384
8	6 48 45.37	+1.03	+ 9 38 24.6	— 0.2	Σ. 986
9	6 49 2.71	+1.03	+ 9 47 25.0	— 0.3	Weisse's Bessel 1437
10	6 46 50.47	+1.33	+ 8 47 58.7	— 0.2	Grant 1676
11	6 40 34.76	+1.45	+ 8 28 52.3	+ 0.2	Grant 1647
12	6 41 14.90	+1.47 +1.49	+ 8 9 24.9	+ 0.2	Grant 1649
13					DM. +7° 1467
14	6 26 50.90	+1.68	+ 7 24 51.2	+ 0.7	½(Gr. 1864+H.C. 1875)
15	6 25 44.61	+1.82 +1.84	+ 6 51 53.9	+ 0.7	Schjellerup 2241
16	6 9 40.00	+2.02	+ 6 6 2.8	+ 1.5	½(Schj. 2109+W. Bessel 210)
17	6 11 10.44	+2.02	+ 6 7 16.1	+ 1.5	Weisse's Bessel 256
18	5 38 48.96	+2.45	+ 3 46 55.6	+ 3.0	Weisse's Bessel 950
19	5 25 21.94	+2.53	+ 3 12 17.9	+ 3.5	Grant 1348
20	9 50 33.91	+1.21	—15 0 51.5	+ 0.5	Weisse's Bessel 1054
21	9 53 4.89	+1.46	—13 24 23.7	— 1.4	Lalande 19530
22	10 9 25.19	+1.65	—11 27 21.5	— 3.7	Lalande 19930
23	10 12 13.82	+1.64	—11 31 13.4	— 3.6	Weisse X, 165
24	10 9 42.81	+1.64	—11 14 1.8	— 3.9	Armagh (2) 1189
25	2 0 19.06	+2.96	+13 33 54.0	+13.8	Weisse's Bessel 1039

The observers are FRISBY, WINLOCK and TUTTLE.

DISCOVERY AND OBSERVATIONS OF COMET 1888 *f*,

BY E. E. BARNARD, ASTRONOMER OF THE LICK OBSERVATORY.

On the morning of October 31, after closing observations with the 12-inch equatorial, I began comet-seeking with the 4-inch broken-tube comet seeker. A faint and suspicious object being swept up, it was examined with the 12-inch, and was at once seen to be a comet; the head was moderately well developed, with an ill-defined nucleus, and a short, faint tail preceding. I estimated the comet to be between the eleventh and twelfth magnitudes. The observations clearly showed motion towards the northeast. A telegram was at once sent out announcing the discovery, and giving the daily motions as $+1^m\ 32^s$ and $+9'$. These values, derived from the observations during the short time the comet was seen, proved to be very close to the true ones.

Following are the observations so far obtained of the comet. These are corrected for differential refraction.

1888 Mt. Hamilton M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Oct. 30 16 50 55	1	12 , 7	—2 17.59	+ 2 38.6	9 43 22.03	—15 18 43.2	n9.417	0.827
31 16 33 59	1	6 , 8	—0 45.16	+11 37.3	9 44 54.49	—15 9 45.1	n9.453	0.821
Nov. 1 16 33 8	2	10 , 7	+1 30.56	— 9 42.5	9 46 26.01	—15 0 27.6	n9.450	0.822
16 33 8	3	10 , 8	+0 13.53	— 8 50.6	9 46 25.65	—15 0 27.5	n9.450	0.822
2 16 13 31	3	6 , 8	+1 42.68	+ 0 24.3	9 47 54.80	—14 51 12.8	n9.504	0.816
3 17 1 48	3	5 , 6	+3 14.65	+10 19.1	9 49 26.83	—14 41 18.1	n9.352	0.828
4 16 58 30	4	4 , 6	+0 30.74	— 4 58.6	9 50 54.27	—14 31 26.5	n9.360	0.826
5 16 49 57	5	4 , 3	+0 32.14	+ 0 12.3	9 52 19.64	—14 21 26.4	n9.380	0.823
6 17 5 49	6	5 , 6	—0 35.21	— 9 12.2	9 53 44.67	—14 11 17.2	n9.310	0.826
7 16 9 2	6	8 , 7	+0 44.60	+ 0 40.8	9 55 4.51	—14 1 23.7	n9.479	0.814
8 15 13 35	7	8 , 1	—0 11.12	± 0 0.0	9 56 22.96	—13 51 15.9	n9.579	0.796
10 15 59 39	8	14 , 6	—0 7.32	— 0 17.1			n9.480	0.812
11 17 3 51	9	8 , 6	—2 8.30	± 0 0.0	10 0 24.44	—13 17 33.2	n9.299	0.822

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Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	9 45 38.51	+1.11 +1.14	—15 21 23.1	+0.8 +0.7	½(W.B. IX, 958+Santini 999)
2	9 44 54.29	+1.16	—14 50 45.6	+0.5	½(W.B. IX, 947+Santini 998)
3	9 46 10.96	+1.16 +1.16 +1.22	—14 51 37.4	+0.5 +0.3 +0.2	½(W.B. IX, 967+Santini 1001)
4	9 50 22.30	+1.23	—14 26 27.8	—0.1	Compared with Argentine G.C. 13425
5	9 51 46.24	+1.26	—14 21 38.0	—0.7	" " " " "
6	9 54 18.59	+1.29 +1.32	—14 2 4.4	—0.6 —0.7	Compared with ½(W.B. IX, 1178+Lamont 630)
7	9 56 32.73	+1.35	—13 51 14.9	—1.0	½(W.B. IX, 1178+630 Lamont)
8	9 59 4	+1.41	—13 29	—1.3	S.DM., —13° 3024
9	10 2 31.33	+1.41	—13 17 31.6	—1.6	Santini 1025

Lick Observatory, 1888 *Nov.* 13.

OBSERVATIONS OF COMET 1888 *c* (*BROOKS*),

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY,

BY O. C. WENDELL, ASSISTANT.

[Communicated by Professor EDWARD C. PICKERING, Director.]

1888 Greenwich M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″	s	″
Aug. 27 13 1 57	1	6	+0 17.32	— 1 52.9	12 40 57.53	+39 42 2.3	9.754	0.665
13 30 0	2	5	+0 25.92	— 2 34.2	12 41 6.13	+39 41 21.0	9.751	0.710
29 14 32 36	3	4	+1 12.90	+ 1 34.6	12 55 19.92	+38 27 2.0	9.715	0.791
Sept. 5 14 35 10	4	5	+1 6.45	— 0 51.6	13 39 52.65	+33 33 56.8	9.698	0.784
6 12 41 18	5	5	+0 12.96	— 2 39.4	13 45 13.69	+32 52 14.4	9.709	0.637
24 13 21 13	6	3	+3 24.78	— 4 45.3	15 9 34.24	+18 57 16.2	9.663	0.738
26 12 56 32	7	6	+0 19.97	+ 3 35.2	15 16 53.58	+17 31 46.3	9.654	0.726
Oct. 8 13 1 16	8	6	—1 23.40	— 9 29.1	15 55 36.36	+ 9 45 52.3	9.644	0.758
10 12 52 39	9	5	—1 48.06	—12 23.8	16 1 16.49	+ 8 37 40.6	9.641	0.758

Mean Places for 1888.0 of Comparison-Stars.

*	Mag.	α	Red. to app. place	δ	Red. to app. place	Authority	Remarks
		h m s	s	° ′ ″	″		
1	9.5	12 40 40.70	—0.49	+39 43 48.7	+6.5	B.B. VI, +39° 2559	
2	9.5	12 40 40.70	—0.49	+39 43 48.7	+6.5	B.B. VI, +39° 2559	
3	8.6	12 54 7.45	—0.43	+38 25 20.5	+6.9	W. Bessel 12^h 1046	Comet rather low and faint
4	9.1	13 38 46.43	—0.23	+33 34 40.4	+8.0	W. Bessel 13^h 781	" " " " "
5	9.3	13 45 0.94	—0.21	+32 54 45.6	+8.2	10 comparisons with Weisse's Bessel 13h 932	
6	8.5	15 6 9.34	+0.12	+19 1 52.7	+8.8	W. Bessel 15^h 85	Stopped by increasing fog (2/3 wt.)
7	9.1	15 16 33.42	+0.19	+17 28 2.0	+9.1	6 comparisons with Weisse's Bessel 15h 415	
8	9.2	15 56 59.47	+0.29	+ 9 55 13.0	+8.4	B.B. VI, 2943	Comet very faint. Obs. difficult
9	6.4	16 3 4.23	+0.32	+ 8 49 56.1	+8.3	W. Bessel 16^h 1	Comet very faint. Obs. rather difficult

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ELEMENTS AND EPHEMERIS OF COMET 1888*f* (*BARNARD*),

BY W. C. WINLOCK.

[Communicated by the Superintendent of the U.S.N. Observatory.]

The following elements were computed from the mean of the Albany, Cambridge and Washington observations of Nov. 1, and the Washington observations of Nov. 11 and 20.

$$T = 1888 \text{ Sept. } 17.171 \text{ Greenw. M.T.}$$

$$\left.\begin{aligned}\omega &= 296^\circ\ 54'.8\\ \Omega &= 137\ \ 38.5\\ i &= 58\ \ 22.3\end{aligned}\right\}\text{Equin. } 1888.0$$

$$\log q = 0.21258$$

Middle place (O—C) $\Delta\lambda \cos\beta = +1'.5$, $\Delta\beta = 0.0$

EPHEMERIS FOR GREENWICH MEAN TIME.

1888	α h m s	δ ° ′	log r	log Δ	Bright
Nov. 25.5	10 15 11	—10 23.0	0.2728	0.2264	1.03
26.5	16 6	10 7.9			
27.5	16 59	9 52.5			
28.5	17 51	9 36.7			
29.5	18 41	9 20.7	.2788	.2187	1.04
30.5	19 30	9 4.3			
Dec. 1.5	20 17	8 47.5			
2.5	21 2	8 30.3			
3.5	21 45	8 12.7	0.2849	0.2108	1.05
4.5	22 26	7 54.7			
5.5	23 6	7 36.4			
6.5	23 44	— 7 17.7			
Dec. 7.5	10 24 20	— 6 58.5	0.2911	0.2027	1.05
8.5	24 54	6 38.9			
9.5	25 27	6 18.9			
10.5	25 57	5 58.5			
11.5	26 26	5 37.7	.2975	.1946	1.06
12.5	26 52	5 16.4			
13.5	27 17	4 54.7			
14.5	27 40	4 32.5			
15.5	28 1	4 9.9	.3039	.1865	1.07
16.5	28 20	3 46.8			
17.5	28 38	3 23.2			
18.5	28 53	2 59.1			
19.5	29 6	2 34.6	.3103	.1787	1.08
20.5	29 17	2 9.6			
21.5	29 26	1 44.1			
22.5	29 33	1 18.1			
23.5	29 38	0 51.7	.3169	.1712	1.08
24.5	29 41	— 0 24.8			
25.5	29 42	+ 0 2.5			
26.5	29 40	0 30.3			
27.5	10 29 37	+ 0 58.6	0.3234	0.1644	1.09

The brightness on Nov. 1 is taken as unity.

CORRIGENDA IN No. 184.

Page 126, column 1, line 1, *dele* "or."
" " " 13, for *m* put m^2.
" " " 6 from below, for *f* put *f′*.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 186.

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ON THE COLORS OF THE VARIABLE STARS,

By S. C. CHANDLER.

The purpose of this article is to communicate the results of the series of observations on the redness of the variable stars which were incorporated in my Catalogue (No. 179–180 of this Journal) as briefly described in the introduction thereto.

I had long been impressed with the importance of an investigation of the sort in question, but had been deterred from undertaking it by the difficulties, physical and physiological, in devising a rational and practical method, and the establishment of a correct color-scale. Nevertheless there was a prospect that something of value could be accomplished in this direction, without waiting until these obstacles to a complete solution of the problem should be surmounted. I therefore began, in April, 1883, a series of estimates, with my 6¼-inch Clacey refractor, upon a large number of the telescopic variables, according to a plan proposed first by Klein, and afterwards pursued by Schmidt so industriously and satisfactorily in its application to the brighter stars, and later still by Safarik and Dunér. It did not seem best to attempt to conform my scale to that of Schmidt, as the effort would in all likelihood fail, and in no event could a comparison between estimates by two observers be directly made, without an investigation of the relation between their scales. For the same reason I shall not here attempt to convey, by ampler verbal description, any more definite idea of the character of the imaginary decimal scale to which I sought to conform, than is contained in the introduction to my Catalogue; which description is here repeated for convenience. The 0 corresponds to white light; 1 to the slightest perceptible admixture of yellow with the white; 2 to yellow; 3 to yellowish orange; 4 to full orange or orange-red; 5 to 10 to increasing shades of intensity up to the nearest approach to pure red light of which we have cognizance in the heavens, exemplified nearly by such stars as *S Cephei*, *V Cygni* and *R Leporis*. It is freely admitted that there is much vagueness in this description, as well as in the mental picture of the imaginary standards to which it was sought to refer the estimates. The difficulty is inherent, and has been experienced by other observers. Indeed, in the beginning, before confidence had been acquired by practice, I strongly doubted whether the method would yield results to be depended upon; but on further acquaintance I am convinced that the certainty of the process of mental reference of color-impressions to imaginary standards, and the fixedness of the latter, are greater than would be naturally inferred by an observer previous to trial.

An independent means of judging of the trustworthiness of the results was obtained by a series of color-measurements by a totally different method, which were begun later in the same year, and carried on, parallel with the first series, to their termination in June, 1884. In casting about for some simple means of verifying the decimal scale estimates, after making various desultory and unsatisfactory experiments, with a direct-vision prism, and otherwise, I finally hit upon what seems to be an effective way of easily recognizing differences of color, and of numerically estimating their relative amount with great certainty — although upon an entirely arbitrary scale. The accuracy with which the relative value of moderate differences of brightness can be estimated by Argelander's method, suggested the idea of converting the difference of color between two stars into difference of brightness, thus changing the element to be directly observed from a very uncertain, to a very certain one. This conversion was effected in a simple manner, by interposing a shade of colored glass, which, by its selective absorption, alters the apparent relative brightness of stars of different colors. Thus, a red star which appears exactly equal to a white one, when viewed in the ordinary way, appears fainter than the latter when a blue shade-glass is applied to the eyepiece, and brighter when a red shade-glass is used. These differences, which can be estimated very precisely by Argelander's method, thus become measures of the difference of color, of course on an entirely arbitrary scale, depending on the amount and character of the selective absorption of the shades employed.

By this simple method were made the series of measurements whose results are presently to be given under the name of "Relative-Diminution Estimates." The particular

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shade-glass used was of a weak blue tint, selected so that the relative diminution of variables of average redness, with reference to white stars, was about half a magnitude. The practical process of conducting each observation was as follows. The variable being brought near the center of the field, a comparison-star was chosen, as nearly as possible free from perceptible color, and nearly of the same brightness — preferably a trifle fainter than the variable. Suppose the comparison showed the variable to be 3 steps brighter, for example. The blue shade was then applied and the comparison was repeated. Suppose the variable appeared now to be 4 steps fainter. The "relative diminution" of brightness was therefore 7 steps; and similar comparisons being made with one or two other stars in the field, to reduce the effect of marked color in either of them, the mean was recorded as the result of the observation.

The table on page 139 contains the results of all the observations made by both methods above described. It comprises 665 "Decimal-Scale Estimates" upon 108 telescopic variables, and 287 "Relative-Diminution Estimates" upon 77 of the same stars, giving an average of nearly nine estimates of the color of each star. The table contains, against each star, indicated by its catalogue-number and name, the number and average value, A, of the decimal-scale estimates, and the number and average value, B, of the relative-diminution estimates. The column C is the value of B reduced to the scale of A by means of the table of reduction hereafter given. The last column, headed "Mean," is the mean of A and C, taken with regard to the number of observations, and is the value of the redness inserted in the tenth column of my Catalogue of Variables.

The table for reducing the values B to the scale of A is here given.

A	*B*	*A*	*B*	*A*	*B*	*A*	*B*
0.0	2.0	2.5	2.8	5.0	4.7	7.5	8.5
0.5	2.1	3.0	3.0	5.5	5.2	8.0	10.0
1.0	2.2	3.5	3.4	6.0	5.8	8.5	12.0
1.5	2.4	4.0	3.8	6.5	6.5	9.0	16.0
2.0	2.6	4.5	4.2	7.0	7.4	10.0	20.0

This table was derived graphically from the 68 stars for which measures existed by both methods. The resulting curve seemed to indicate that the zeros of the two scales do not correspond. Different interpretations may be placed upon this fact, and there is consequently much uncertainty as to the real relation of the two scales near this end. As the chart cannot be reproduced here, I give instead the means, in groups of five stars each, of both sets of measures, after they had been arranged in order of the decimal-scale estimates. The column C contains, as before, the values of B reduced to the scale of A; and the last column is the difference between the mean values of the groups by both methods.

Stars	*A*	*B*	*C*	*A—C*
5	0.36	1.32	0.00	+0.36
	0.88	2.88	2.70	—1.82
5	1.30	2.32	1.25	+0.05
5	1.82	2.54	1.90	—0.08
5	2.16	2.60	2.12	+0.04
5	2.74	3.00	2.90	—0.16
5	3.16	3.14	3.14	+0.02
5	3.52	2.92	2.80	+0.72
5	4.16	4.04	4.28	—0.12
5	4.86	4.68	4.95	—0.09
5	5.78	5.62	5.82	—0.04
5	6.50	6.40	6.42	+0.08
4	7.35	10.25	8.05	—0.70
4	9.10	14.42	8.80	+0.30

One important point to investigate is the effect of the brightness of the star upon the estimate of its color. The lower limit of visibility of the telescope was about 13^{M}; the objects observed were generally between 7^{M} and 9^{M}, rarely outside the limits 6^{M} and 11^{M}. From the known influence of brightness upon color-impressions, it was natural to expect that the estimates would betray a decided dependence upon magnitude. Careful study fails to reveal it, however. Thus, taking all the distinctly red variables which were observed over a considerable range of brightness, and forming separate means of the scale-estimates near the upper and lower limits of this range, we have the following results.

	Brightness	Redness	Diff.
	M M		
T Cassiopeae	8.3 – 10.5	7.0 – 7.0	0.0
R Aurigae	8.8 – 11.2	6.0 – 6.0	0.0
R Leonis	6.2 – 9.2	7.4 – 6.0	+1.4
V Coronae	7.7 – 9.1	5.3 – 5.7	—0.4
V Ophiuchi	7.9 – 9.7	7.0 – 6.4	+0.6
S Herculis	7.0 – 9.3	4.5 – 6.0	—1.5
R Cygni	7.6 – 9.0	6.0 – 6.5	—0.5
χ Cygni	5.7 – 8.2	7.0 – 6.0	+1.0
U Cygni	8.1 – 11.0	9.0 – 9.0	0.0
V Cygni	8.5 – 11.2	8.3 – 8.0	+0.3
T Cephei	6.6 – 8.7	5.9 – 6.7	—0.8
S Cephei	8.3 – 9.8	9.8 – 8.3	+1.5
R Aquarii	6.7 – 9.6	4.6 – 4.3	+0.3
R Cassiopeae	6.4 – 9.7	6.3 – 7.5	—1.2
Average	7.4 – 9.7	6.72 – 6.67	+0.05

From this it will seen that the effect of brightness upon the scale-estimates is not perceptible, at least within the range of $2^{M}.3$ from $7^{M}.4$ to $9^{M}.7$; the mean difference being only +0.05, with a probable error of ±0.16. Similarly treated, the "relative-diminution" estimates gave, from seven stars, +0.39, with a probable error of ±0.43. We may fairly infer, therefore, that there is little reason to fear serious systematic error of the sort in question.

It is interesting to compare the above results with those of SCHMIDT (*A.N.* 1897, 1902 and 2236). For a reduction of his estimates in the finder to those in the refractor, we might use the numbers given by him, from which I find the relation

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Catal. No.	Star	Scale-Est. No.	Scale-Est. *A*	Rel.-Dim. Est. No.	Rel.-Dim. Est. *B*	Rel.-Dim. Est. *C*	All No.	All Mean
107	*T Cassiopeae*	6	7.3	. . .	. . .	. . .	6	7.3
112	*R Andromedae*	16	5.4	6	3.9	4.1	22	5.0
114	*S Ceti*	1	2.0	. . .	. . .	. . .	1	2.0
432	*S Cassiopeae*	3	6.7	. . .	. . .	. . .	3	6.7
434	*S Piscium*	3	1.0	. . .	. . .	. . .	3	1.0
513	*R Piscium*	7	1.9	1	3.0	3.0	18	2.0
782	*R Arietis*	5	1.4	6	2.7	2.2	1	1.8
806	*o Ceti*	10	6.0	4	5.4	5.7	14	5.9
814	*S Persei*	1	5.0	. . .	. . .	. . .	1	5.0
845	*R Ceti*	5	1.9	4	3.0	3.0	9	2.4
976	*T Arietis*	11	3.8	3	2.2	1.0	14	3.2
1222	*R Persei*	5	2.0	6	2.8	2.5	11	2.3
1577	*R Tauri*	6	4.5	. . .	. . .	. . .	6	4.5
1582	*S Tauri*	4	2.5	. . .	. . .	. . .	4	2.5
1717	*V Tauri*	7	3.4	2	3.0	3.0	9	3.3
1761	*R Orionis*	1	4.0	2	5.0	5.3	3	4.9
1771	*R Leporis*	9	9.7	4	15.3	8.9	13	9.4
1853	*R Aurigae*	5	6.1	5	7.0	6.8	10	6.5
1923	*S Aurigae*	3	6.7	. . .	. . .	. . .	3	6.7
1944	*S Orionis*	3	6.4	. . .	. . .	. . .	3	6.4
2266	*V Monocerotis*	8	3.3	8	3.3	3.4	16	3.4
2478	*R Lyncis*	11	4.5	9	4.8	5.1	20	4.8
2528	*R Geminorum*	3	5.7	2	5.5	5.7	5	5.7
2539	*R Canis minoris*	16	5.6	7	4.9	5.2	23	5.5
2625	*V Geminorum*	9	2.7	2	3.3	3.4	11	2.8
2684	*S Canis minoris*	12	4.2	8	3.7	3.9	20	4.1
2735	*U Canis minoris*	5	5.1	. . .	. . .	. . .	5	5.1
2780	*T Geminorum*	1	3 :	1	3.0	3.0	2	3.0
2815	*U Geminorum*	3	0.0	1	0.0	0.0	4	0.0
2857	*U Puppis*	4	3.2	. . .	. . .	. . .	4	3.2
2946	*R Cancri*	8	5.0	2	6.7	6.7	10	5.3
2976	*V Cancri*	12	4.0	7	4.2	4.5	19	4.3
3060	*U Cancri*	2	1.0	3	3.2	3.2	5	2.3
3170	*S Hydrae*	9	2.0	3	2.7	2.3	12	2.1
3186	*T Cancri*	13	7.2	4	9.5	7.8	17	7.4
3184	*T Hydrae*	9	1.6	7	2.6	2.0	16	1.8
3477	*R Leonis minoris*	2	6.0	. . .	. . .	. . .	2	6.0
3493	*R Leonis*	12	7.1	6	6.5	6.5	18	6.9
3567	*V Leonis*	2	1.7	. . .	. . .	. . .	2	1.7
3825	*R Ursae Majoris*	10	1.6	3	2.5	1.7	13	1.6
3934	*R Crateris*	9	8.6	4	7.5	7.1	13	8.1
3994	*S Leonis*	4	0.0	1	2.0	0.0	5	0.0
4315	*R Comae*	1	4.0	. . .	. . .	. . .	1	4.0
4377	*T Virginis*	1	4.0	1	4.0	4.2	2	4.1
4407	*R Corvi*	8	4.4	7	3.0	3.0	15	3.7
4492	*Y Virginis*	1	3.0	1	4.0	4.2	2	3.6
4511	*T Ursae Majoris*	11	2.0	7	2.6	2.0	18	2.0
4521	*R Virginis*	9	0.9	2	3.0	3.0	11	1.3
4557	*S Ursae Majoris*	13	3.0	6	3.4	3.5	19	3.2
4596	*U Virginis*	10	1.9	7	1.8	0.0	17	1.1
4805	*W Virginis*	4	0.5	1	0.0	0.0	5	0.4
4816	*V Virginis*	4	0.9	3	4.7	5.0	7	2.7
4826	*R Hydrae*	3	5.8	3	5.7	5.9	6	5.9
4847	*S Virginis*	10	3.0	7	2.6	2.0	17	2.6

Catal. No.	Star	Scale-Est. No.	Scale-Est. *A*	Rel.-Dim. Est. No.	Rel.-Dim. Est. *B*	Rel.-Dim. Est. *C*	All No.	All Mean
5157	*S Bootis*	9	3.1	7	2.5	2.4	16	2.8
5194	*V Bootis*	1	3.0	1	4.0	4.2	2	3.6
5190	*R Camelopardalis*	4	3.2	2	1.5	0.0	6	2.1
5237	*R Bootis*	10	3.4	6	2.5	1.5	16	2.7
5338	*U Bootis*	4	2.4	3	3.2	3.2	7	2.7
5484	*U Coronae*	1	0.0	. . .	. . .	. . .	1	0.0
5494	*S Librae*	3	3.0	2	3.0	3.0	5	3.0
5501	*S Serpentis*	4	4.0	5	3.9	4.2	9	4.1
5504	*S Coronae*	2	5.0	1	4.5	4.8	3	4.9
5617	*U Librae*	2	3.5	3	3.2	3.3	5	3.4
5667	*R Coronae*	6	0.5	. . .	. . .	. . .	6	0.5
5677	*R Serpentis*	12	3.5	7	3.8	4.0	19	3.7
5675	*V Coronae*	9	5.7	2	7.0	6.8	11	5.9
5770	*R Herculis*	1	2.0	. . .	. . .	. . .	1	2.0
5830	*R Scorpii*	2	0.0	2	2.5	1.7	4	0.9
5856	*W Ophiuchi*	1	3.0:	. . .	. . .	. . .	1	3.0
5887	*V Ophiuchi*	9	6.5	2	8.0	7.3	11	6.6
5889	*U Herculis*	4	6.5	. . .	. . .	. . .	4	6.5
5948	*R Ursae minoris*	11	3.1	1	4.0	4.2	12	3.2
5955	*R Draconis*	12	2.4	7	2.3	1.3	19	2.0
5950	*W Herculis*	6	2.7	7	3.6	3.7	13	3.2
6044	*S Herculis*	7	5.6	. . .	. . .	. . .	7	5.6
6088	*V Herculis*	1	1.0	. . .	. . .	. . .	1	1.0
6132	*R Ophiuchi*	7	4.3	6	4.4	4.7	13	4.5
6512	*T Herculis*	8	1.6	4	2.2	1.0	12	1.4
6624	*T Serpentis*	1	2.0	. . .	. . .	. . .	1	2.0
6633	*V Sagittarii*	6	0.7	1	2.0	0.0	7	0.6
6636	*U Sagittarii*	4	3.7	. . .	. . .	. . .	4	3.7
6726	*T Aquilae*	6	3.3	. . .	. . .	. . .	6	3.3
6849	*R Aquilae*	8	5.5	. . .	. . .	. . .	8	5.5
6903	*T Sagittarii*	2	6.5	. . .	. . .	. . .	2	6.5
6905	*R Sagittarii*	3	3.6	. . .	. . .	. . .	3	3.6
7045	*R Cygni*	11	6.1	4	5.3	5.6	15	6.0
7106	*S Vulpeculae*	11	3.4	3	2.3	1.3	14	3.0
7120	*χ Cygni*	10	6.8	2	5.0	5.3	12	6.5
7220	*S Cygni*	1	5.0	1	5.0	5.3	2	5.1
7242	*S Aquilae*	4	1.0	1	2.0	0.0	5	0.8
7257	*R Sagittae*	9	1.0	2	2.0	0.0	11	0.8
7261	*R Delphini*	3	4.0	. . .	. . .	. . .	3	4.0
7299	*U Cygni*	10	9.0	5	20.0	10.0	15	9.3
7194	*R Cephei*	3	0.7	1	1.0	0.0	4	0.5
7431	*S Delphini*	3	6.0	. . .	. . .	. . .	3	6.0
7428	*V Cygni*	9	8.1	1	20.0	10.0	10	8.3
7444	*T Delphini*	2	2.0	. . .	. . .	. . .	2	2.0
7468	*T Aquarii*	4	1.5	1	1.5	0.0	5	1.2
7560	*R Vulpeculae*	3	0.6	4	3.1	3.1	7	2.0
7609	*T Cephei*	11	6.2	5	6.4	6.4	16	6.3
7779	*S Cephei*	12	9.2	4	15.5	8.9	16	9.1
7803	*μ Cephei*	1	7.0	1	5.0	5.3	2	6.2
8153	*R Lacertae*	6	2.0	2	2.2	1.0	8	1.8
8230	*S Aquarii*	1	4.0	. . .	. . .	. . .	1	4.0
8373	*S Pegasi*	8	1.8	5	2.4	1.5	13	1.7
8512	*R Aquarii*	10	4.2	3	4.2	4.5	13	4.3
8600	*S Cassiopeae*	17	6.7	7	5.7	5.9	24	6.5

$R = 1.17\,S - 1.5$. But these numbers were deduced very largely from bright stars. I have preferred, therefore, to use a relation derived entirely from the color-estimates upon the variables themselves, namely, $R = 1.22\,S - 1.0$. Combining his two sets of estimates, reduced to the scale of the refractor by this relation, and with regard to the number of observations, we have for the stars common to SCHMIDT's and my series, and of which there are more than one observation, the values headed by the observers' names below.

It is evident that the relation between the two scales is not a linear one. A unit of my scale near the least refrangible portions corresponds to much less than a unit of

SCHMIDT's, while the reverse is true near the other end. In the column of "Reduced" values are placed SCHMIDT's estimates converted to my scale by the expression,

$$C = 3.1 - 1.8\ S + 0.3\ S^2;$$

arbitrarily modified, however, by taking, for all values of S less than 3.0, the reduced value 0.4. The last column gives the differences of the two sets of estimates. Ignoring the difference in the number of observations, the probable error of the difference between two observers, for a single star, is ±0.73; and that for the estimate by one observer is ±0.51. But a trustworthy determination of this quantity would require much more data.

Star	SCHMIDT	Reduced	CHANDLER	$S-C$
R Leporis	7.89	7.6	9.4	—1.8
R Leonis	7.65	6.9	6.9	0.0
χ Cygni	7.42	6.3	6.5	—0.2
μ Cephei	8.30	8.8	6.2	+2.6
R Cygni	7.40	6.2	6.0	+0.2
R Hydrae	7.40	6.2	5.9	+0.3
o Ceti	6.93	5.0	5.9	—0.9
R Cancri	7.59	6.7	5.3	+1.4
S Coronae	6.68	4.5	4.9	—0.4
R Aquarii	6.63	4.4	4.3	+0.1
R Serpentis	5.60	2.4	3.7	—1.3
R Bootis	5.80	1.8	2.7	—0.9
R Herculis	6.50	4.0	2.0	+2.0
R Ursae Maj.	6.23	3 5	1.6	+1.9
R Virginis	5.23	1.9	1.3	+0.6
R Coronae	3.90	0.6	0.5	+0.1
R Cephei	3.25	0.4	0.5	—0.1
W Virginis	2.67	0.4	0.4	0.0
U Coronae	2.28	0.4	0.0	+0.4

One important aim in undertaking the series of observations given in this article was the investigation of the interesting connection which appears to subsist between the color of the variables and their periods. The existence of such a relation was pointed out first by SCHMIDT, and shortly afterwards independently by the writer; but the material by which it was sought to establish the fact was meagre and unsatisfactory. The present series of color-determinations goes far to remedy these defects. Arranging all the periodical variables on page 139 in order of the periods assigned in my Catalogue, and taking the average period and color in groups, we have the following table.

Number	Stars Obs.	Period of Group Limits	Mean	Mean Redness A	B
		d d	d		
4	42	607.5 – 482	517.6	7.3	7.8
4	44	461.3 – 436.1	449.8	8.1	8.4
4	52	429 – 416	423.4	6.8	6.7
4	41	411.2 – 406.0	408.4	4.7	5.2
4	51	387.1 – 380	383.6	5.5	5.2
4	26	378.8 – 373.5	376.1	3.9	3.1
4	18	370.5 – 360.6	364.6	4.7	4.7
4	48	359.5 – 352.3	355.6	5.1	4.8
4	33	346 – 337.5	342.5	3.6	4.5
4	34	337 – 331.3	333.5	3.8	4.4
4	28	331 – 324	325.2	3.1	4.0
4	18	324 – 318.4	322.0	3.1	3.3
4	54	317.5 – 312.9	315.6	3.5	4.0
4	35	310 – 305.4	307.9	4.2	4.1
3	34	305.2 – 289.4	299.0	2.9	2.9
4	20	288.7 – 280	285.2	3.0	3.2
4	31	279.3 – 272.3	276.1	3.9	3.2
4	30	271.5 – 266.5	269.4	3.4	3.4
4	56	257.2 – 245.9	252.7	2.2	2.1
4	50	224.5 – 210.4	220.7	2.3	2.7
4	29	210 – 192.3	203.2	2.2	1.6
4	32	186.7 – 169.2	178.7	2.0	2.1
5	44	167.9 – 136.9	153.0	1.6	1.8
5	38	86.3 – 6.7	49.7	1.6	1.8

The mean redness is stated above in two ways; A, giving equal weights to each star; B, giving weights according to the number of observations. Whichever method is chosen, the general progression of the results is remarkable, and cannot be interpreted as fortuitous merely. Besides, many of the variables not included in this series clearly conform to the same law. Thus, all the short-period variables of the *η Aquilae* type are colorless, or nearly so; with the single exception of *U Sagittarii*, which is orange. The light of all the *Algol* type variables, also, is strikingly white, to my eye at least.

In conclusion, I think it may be regarded as established that the redness of the variable stars is, in general, a function of the length of their periods of light-variation. The redder the tint, the longer the period. It is needless to point out the significance of this association of two sets of phenomena, relating in all probability, one to the dynamics of the star, the other to the chemical condition of its photosphere. Its importance as a touchstone for hypotheses in regard to the causes of stellar variability is evident.

ELEMENTS OF COMET 1888 *f*,

BY REV. GEORGE M. SEARLE.

I have computed the following elements for the comet 1888 *f* from the observations at the Lick Observatory on Nov. 1 and 11, with the one made at Washington on Nov. 21.

$$\begin{aligned} T &= 1888 \text{ Sept. } 13.0164 \text{ Greenw. M.T.} \\ \Omega &= 137^\circ\ 36'\ 20'' \\ \omega &= 291\quad 3\quad 26 \\ i &= 56\quad 24\quad 34 \\ \log q &= 0.185607 \end{aligned} \quad \left.\right\} \text{Eq. 1888.0}$$

The middle place is represented as follows, (O—C):

$$\Delta\lambda = -2'' \qquad \Delta\beta = +1''$$

These elements represent a rough observation, which I obtained this morning within about 6ˢ in α, and 0′.5 in δ.

New York, 1888 *Dec.* 7.

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NEW DOUBLE STARS,

DISCOVERED AT THE LICK OBSERVATORY,

By S. W. BURNHAM.

[Communicated by the Director.]

The following new double stars have been found and measured at the Lick Observatory in the last three months. Stars only partially measured are reserved for a future list. The 36 and 12-inch refractors have both been used in this work. When not otherwise stated in the notes to the measures, the stars were discovered with the 12-inch. The instrument used in making the measures is given in the last column.

Lal. 58.

R.A. = 0h 5m 48s. Decl. = +52° 57′.

	°	″		
1888 733	326.0	. .	8 . . 9	12
.736	338.9	0.51	8 . . 8.5	12
.785	322.0	0.43	8 . . 9	12
.796	331.7	0.50	8.5 . . 9	12
1888.76	329.6	0.48	8.1 . . 8.9	

This star is 7M in Lal., and 6M.5 in DM.

W.B. O, 200 = DM.(20°) 15.

R.A. = 0h 8m 44s. Decl. = +20° 50′

	°	″		
1888.815	187.3	1.60	7 . . 10	36
.821	186.1	1.57	7.5 . . 10.5	12
.832	187.1	1.44	7 . . 10.5	12
1888.32	186.8	1.54	7.2 . . 10.3	

Discovered with the 36-inch.

γ Cassiopeae.

R.A. = 0h 48m 50s. Decl. = +60° 1′.

	°	″		
1888.668	255.0	2.17	. . 11	36
.671	255.2	2.13	. .	36
.678	254.7	2.03	. . 11	36
.681	257.5	2.33	. . 11.5	12
.695	254.9	2.26	. . 11	36
.733	258.0	2.17	. . 11	12
1888.69	255.9	2.18	. . 11	

Discovered with the 36-inch.

The following measures were made of the distant companion (β 499):

	°	″		
1888.678	348.8	52.53	. . 14	36
.695	348.4	52.35	. . 13	36

The two sets of measures of this star indicate no change:

	°	″		
1878.80	348.6	52.27	β	2n
1888.69	348.6	52.44	β	2n

ξ Piscium.

R.A. = 1h 7m 27s. Decl. = +6° 56′

B AND C.

	°	″		
1888.681	244.0	0.98	. . 11.5	12
.695	248.2	0.91	. . 10	12
.714	254.7	0.88	. . 11.5	12
.720	247.1	0.94	. . 11.5	12
.733	249.6	0.96	. . 11	12
1888.71	248.7	0.93	. . 11	

A AND B (Σ. 100).

	°	″		
1888.681	63.4	23.75	. .	12
.695	64.0	23.86	. .	12
.698	63.1	23.91	. .	12
.714	63.5	23.61	. .	12
.733	63.6	23.48	. .	12
1888.71	63.5	23.72		

Relatively fixed, but common proper-motion. Σ found:

	°	″
1832.83	63.7	23.46

W.B. III. 5.

R.A. = 3h 3m 17s. Decl. = +21° 17′.

	°	″		
1888.821	162.1	0.64	8 . . 8	12
.832	168.3	0.63	8.5 . . 8.5	12
.835	163.3	0.47	8.6 . . 8.6	12
1888.83	164.6	0.58	8.4 . . 8.4	

Discovered with the 36-inch.

α Tauri.

R.A. = 4h 29m 2s. Decl. = +16° 16′

A AND B (= β 550).

	°	″		
1888.813	110.0	30.88	. .	36
.835	109.0	30.91	. .	36
1888.82	109.5	30.90		

A AND C (= Σ. 2 App. II).

	°	″		
1888.772	35.7	116.98	. .	36
.813	34.5	116.88	. .	36
.832	34.5	116.86	. .	12
1888.81	34.9	116.91		

C AND D.

	°	″		
1888.772	286.0	3.02	. . 12	36
.813	279.5	2.00	9 . . 12	36
.835	277.7	2.00	9 . . 12	36
1888.81	281.1	2.34	9 . . 12	

The faint star near the old companion was found with the 36-inch.

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σ *Orionis.*

R.A. = 5h 32m 43s. Decl. = −2° 40′

A and B.

	°	″		
1888.775	358.3	0.18	4 . . 6	12
.813	356.2	0.27	4 . . 6	36
.818	356.4	0.27	. .	36
.832	357.1	0.32	. .	36
1888.81	357.0	0.26		

AB and C (Σ. 762).

	°	″		
1888.832	236.7	11.04	. .	12
.832	236.8	11.42	. .	36
.851	237.9	11.24	. .	12
1888.84	237.1	11.23		

AB and D (Σ. 762).

	°	″		
1888.832	83.9	12.90	. .	12
.832	83.2	12.97	. .	36
.851	82.8	12.66	. .	12
1888.84	83.3	12.84		

AB and E.

	°	″		
1888.851	60.5	41.18	. .	12

No change in the old companions. Σ gives

	°	″
1831.42	236.5	11.00
1831.20	84.5	12.86

The close pair is difficult with the 12-inch, with which it was discovered.

ν² *Sagittarii.*

R.A. = 18h 47 51m. Decl. = −22° 49′.

	°	″		
1888.681	104.0	1.37	5½ . . 11	12

Discovered with the 36-inch.

F. 7 *Aquarii.*

R.A. = 20h 50m 25s. Decl. = −10° 9′

	°	″		
1888.600	164.6	1.90	7 . . 13	12
.613	168.1	2.03	6 . . 12	12
1888.714	165.3	2.21	6 . . 11	12
.731	162.9	2.15	6 . . 11.5	12
.733	164.0	2.18	6 . . 11	12
1888.68	165.0	2.09	6 . . 11.7	

Mt. Hamilton, 1888 *Nov.* 15.

Found with the 36-inch.

B.A.C. 7422.

R.A. = 21h 17m 46s. Decl. = −26° 4′.

	°	″		
1888.714	199.2	0.96	8 . . 10.5	12
.733	199.9	1.08	8 . . 11	12
.777	197.1	1.10	8 . . 10.5	12
1888.74	198.7	1.05	8 . . 10.7	

Yar. 9529.

R.A. = 21h 40m 59s. Decl. = −17° 51′

	°	″		
1888.675	204.8	4.62	7.5 . . 11.5	12
.763	204.4	4.67	8 . . 11	12
.777	205.7	4.30	8.5 . . 11	12
1888.74	205.9	4.53	8 . . 11	

W.B. XXII, 854 = DM. (12°) 4888.

R.A. = 22h 41m 56s. Decl. = +12° 22′.

	°	″		
1888.777	226.6	. .	. .	12
.796	221.9	0.72	8.5 . . 10.8	12
.832	228 2	0.68	8.5 . . 10.5	12
.835	220.9	0.58	9 . . 11	12
1888.81	224.4	0.66	8.7 . . 10.8	

The preceding star of a wide pair. Found with the 36-inch.

DM. (41°) 4881.

R.A. = 23h 45m 31s. Decl. = +41° 25′.

	°	″		
1888.681	160.5	0.64	8 . . 8	12
.755	157.5	0.55	8.5 . . 8.5	12
.763	154.9	0.62	8.3 . . 8.3	12
1888.73	157.6	0.60	8.3 . . 8.3	

In DM. 6M.7, but 7M.4 in Radcliffe.

EPHEMERIS OF COMET 1888 *e* (*BARNARD*),

By LEWIS BOSS.

The elements of this comet published in No. 182 of the Journal, appear to be still sufficiently exact for the construction of convenient ephemerides. I therefore transcribe there the elements reduced to 1889.0, together with the corrections necessary to reduce them to 1888.0.

$$
\begin{array}{rcl|l}
T & = & \text{1889 January 31.2269, G.M.T.} & \\
\omega & = & 340^\circ\ 30'\ 28''.8 & -\ 0''.2 \\
\Omega & = & 357\ \ 26\ \ 43\ .1 & -50\ .4 \\
i & = & 166\ \ 22\ \ 11\ .0 & -\ 0\ .5 \\
\log q & = & 0.258795 &
\end{array}
$$

In like manner the heliocentric coordinates of the comet are expressed by the following equations, where the epoch for the quantities is 1889.0, and the quantities following them respectively are the reductions to 1888.0.

$$
\begin{array}{l}
x = r\,[9.999976 \mid +\ 0]\,(v +\ \ 72^\circ\ 59'\ 27''.0 \mid +\ 48''.8) \\
y = r\,[9.993569 \mid +\ 0]\,(v + 162\ \ 53\ \ 11\ .4 \mid +\ 46\ .7) \\
z = r\,[9.233374 \mid +15]\,(v + 166\ \ 27\ \ 27\ .6 \mid +116\ .9)
\end{array}
$$

By an observation at Albany Dec. 12.55, Gr. M.T., the ephemeris of which the following is a continuation required the corrections: $\Delta\alpha = +1^s.3$, $\Delta\delta = +0'.3$.

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1888-9	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
Dec. 19.5	0 50 36	−7 41.0	0.27746	0.1646	7.7
20.5	0 47 21	7 40.7	0.27664	0.1712	
21.5	0 44 15	7 40.0	0.27503	0.1778	
22.5	0 41 16	7 39.0	0.27494	0.1843	
23.5	0 38 25	7 37.7	0.27426	0.1907	7.0
24.5	0 35 40	7 36.2	0.27350	0.1971	
25.5	0 33 3	7 34.4	0.27276	0.2035	
26.5	0 30 32	7 32.4	0.27204	0.2098	
27.5	0 28 8	7 30.1	0.27133	0.2161	6.3
28.5	0 25 50	7 27.6	0.27064	0.2223	
29.5	0 23 37	7 25.0	0.26997	0.2284	
30.5	0 21 30	7 22.2	0.26932	0.2345	
31.5	9 19 29	7 19.3	0.26868	0.2405	5.7
Jan. 1.5	0 17 33	7 16.3	0.26806	0.2464	
2.5	0 15 42	7 13.1	0.26746	0.2522	
3.5	0 13 56	7 9.8	0.26688	0.2579	
4.5	0 12 14	7 6.4	0.26632	0.2635	5.2
5.5	0 10 36	7 2.9	0.26578	0.2690	
6.5	0 9 3	6 59.2	0.26526	0.2745	
7.5	0 7 33	6 55.4	0.26476	0.2799	
8.5	0 6 8	−6 51.6	0.26427	0.2852	4.7
Jan. 9.5	0 4 46	−6 47.7	0.26381	0.2904	
10.5	0 3 28	6 43.7	0.26336	0.2955	
11.5	0 2 13	6 39.6	0.26294	0.3005	
12.5	0 1 1	6 35.5	0.26253	0.3055	4.3
13.5	23 59 52	6 31.4	0.26215	0.3103	
14.5	23 58 47	6 27.2	0.26178	0.3150	
15.5	23 57 44	6 23.0	0.26144	0.3197	
16.5	23 56 44	6 18.7	0.26111	0.3243	4.0
17.5	23 55 46	6 14.4	0.26081	0.3288	
18.5	23 54 51	6 10.0	0.26053	0.3332	
19.5	23 53 58	6 5.6	0.26027	0.3375	
20.5	23 53 8	6 1.1	0.26003	0.3418	3.7
21.5	23 52 20	5 56.7	0.25981	0.3460	
22.5	23 51 34	5 52.2	0.25961	0.3501	
23.5	23 50 50	5 47.7	0.25934	0.3540	
24.5	23 50 8	5 43.1	0.25928	0.3579	3.5
25.5	23 49 28	5 38.5	0.25915	0.3617	
26.5	23 48 50	5 33.9	0.25903	0.3654	
27.5	23 48 13	5 29.3	0.25894	0.3691	
28.5	23 47 38	−5 24.6	0.25887	0.3727	3.2

THE PROBLEM OF ALIGNMENT,

By A. HALL.

Mr. H. P. Tuttle has called my attention to this old method of determining the position of a comet from the intersection of two great circles, each of which passes through two known stars. The problem of finding the right-ascension and declination of the comet from this intersection has been solved by Pingré in his *Cometographie*, Tome II, p. 221. This question can be solved also, and in a very simple manner, by means of the formula employed by Gauss, which expresses the condition that three points on the sphere lie on a great circle. Let α, δ be the right-ascension and declination of the comet, and denote by α_1, δ_1, α_3, δ_3, α_2, δ_2, α_4, δ_4, corresponding quantities for the stars. By the *Theoria Motus*, Art. 113, we have

$$\tan\delta\sin(\alpha_2-\alpha_1)+\tan\delta_1\sin(\alpha-\alpha_2)+\tan\delta_2\sin(\alpha_1-\alpha)=0$$
$$\tan\delta\sin(\alpha_4-\alpha_3)+\tan\delta_3\sin(\alpha-\alpha_4)+\tan\delta_4\sin(\alpha_3-\alpha)=0$$

Equating values of $\tan\delta$ and reducing:

$$\tan\alpha=\frac{[\tan\delta_1\sin\alpha_2-\tan\delta_2\sin\alpha_1]\sin(\alpha_4-\alpha_3)+[\tan\delta_4\sin\alpha_3-\tan\delta_3\sin\alpha_4]\sin(\alpha_2-\alpha_1)}{[\tan\delta_1\cos\alpha_2-\tan\delta_2\cos\alpha_1]\sin(\alpha_4-\alpha_3)+[\tan\delta_4\cos\alpha_3-\tan\delta_3\cos\alpha_4]\sin(\alpha_2-\alpha_1)}$$

When α is found, either of the original equations will give δ.

1888 *December* 1.

NOTE ON THE SATELLITE OF *NEPTUNE*,

By SIMON NEWCOMB.

In No. 178 (Vol. VIII, p. 78) of the *Astronomical Journal*, Professor Hall calls attention to the apparent motion of the plane of the orbit of this satellite, and remarks that it cannot be accounted for by any known cause. There is, however, a possible and not improbable cause for such a motion, namely, the ellipticity of the planet. If the plane of the orbit does not coincide with the equator of the planet, such a motion would be the necessary result, the pole of the orbit revolving around that of the planet with a uniform motion. By observing the position of the former through a considerable fraction of a revolution, the position of the latter can thence be inferred.

Washington, 1888 *December* 2.

By an interesting coincidence, an elaborate article, on the same subject and fully developing the same view, was presented to the French Academy of Sciences by Mr. Tisserand, on Nov. 19. The number of the *Comptes Rendus* for that session was, however, no received here until Dec. 10. G.

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ORBIT AND EPHEMERIS OF THE COMET 1888 *f* (*BARNARD*),

BY J. M. SCHAEBERLE, ASTRONOMER OF THE LICK OBSERVATORY.

[Communicated by the Director.]

From Mr. BARNARD's observations of Oct. 31, Nov. 2, and Nov. 4, I have computed the following orbit and ephemeris of this comet:

$$\begin{aligned} T &= \text{Sept. } 9.4475 \\ \omega &= 267^\circ\ 9'.9 \\ \Omega &= 137\ \ 52.0 \\ i &= 45\ \ 52.6 \\ \log q &= 0.04984 \end{aligned} \left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} \text{Apparent equinox}$$

Middle place (O.—C.)

$$\Delta\lambda \cos\beta = -0'.2 \qquad \Delta\beta = +0'.2$$

Helioc. coordinates:

$$\begin{aligned} x &= r\ [9.94271]\ \sin(144^\circ\ 57'.7+v) \\ y &= r\ [9.99009]\ \sin(\ 48^\circ\ \ 8'.5+v) \\ z &= r\ [9.72089]\ \sin(297^\circ\ 40'.5+v) \end{aligned}$$

Assuming that the above orbit is approximately correct, I find that at the time of perihelion-passage the comet was in right-ascension $10^h\ 30^m$, and south decl. 21° 44', and the brightness less than twice what it was at the time of discovery. The comet will continue to decrease in brightness, although for several weeks to come its distance from the earth will keep on diminishing. On Dec. 5 and Dec. 25 the computed light will be 0.68 and 0.60 respectively, that for Nov. 3.5 being unity.

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

Date	R. A.	Decl.	log r	log Δ	Br.
	h m s	°			
Nov. 3.5	9 48 42	—14 46.9	0.1527	0.1531	1.00
" 7.5	9 54 15	—14 7.6	0.1644	0.1533	0.95
" 11.5	9 59 20	—13 25.9	0.1760	0.1527	0.90
" 15.5	10 3 51	—12 42.1	0.1875	0.1514	0.86

RECENT ASTEROIDS.

In no. 184 of this Journal, p. 128, the number 280 was assigned to the asteroid discovered by PALISA Oct. 31.

But in a subsequent communication of Dr. PALISA to the *Astronomische Nachrichten*, no. 2866. he announces that, on Oct. 29, while searching for *Oppavia*, no. 255, he had observed a small planet, $13^M.7$.

Oct. 29, $9^h\ 50^m\ 31^s$ Vienna M.T.

$$\alpha = 1^h\ 59^m\ 56^s.6 \qquad \delta = +17^\circ\ 15'\ 55''$$

Subsequent observations showed its daily motion to be -54^s in α and $-2'.3$ in δ; while that of no. 255 should, according to the ephemeris. be -58^s and $-2'.5$. No telegram was issued, but the identity of the two now appears scarcely probable.

A later observation by PALISA gave

Nov. 5, $8^h\ 38^m\ 34^s$ Vienna M.T.

$$\alpha = 1^h\ 53^m\ 42^s.0 \qquad \delta = +16^\circ\ 58'\ 59''$$

In case this asteroid of Oct. 29 was not no. 255, it will of course be no. 280; and that of Oct. 31 will thus become no. 281. But it will evidently be well to wait for a while before definitely assigning the number.

The system of numerical notation is meeting obstacles from a source by no means anticipated at the beginning.

G.

CORRIGENDA.

No. 185, Observations of Comet 1888 *f*.

		for	put
Page 133, Nov. 1, Wash. M.T.,		$15^h\ 31^m\ 54^s.2$	$16^h\ 31^m\ 44^s.3$.
" " "	Declination,	—15° 1' 37".0	15° 1' 38".0.
" " Nov. 11,	"	—13 20 0 .4	—13 19 56 .9.
Page 134, Star 21,	"	—13 24 23 .7	—13 24 20 .2.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 187.

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OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS IN 1888,

BY PAUL S. YENDELL.

R Ursae Majoris.

A series of twenty-five observations of *R Ursae Majoris*, extending from Sept. 2 to Dec. 2, indicates a maximum on Oct. 22. When first observed, its brightness was estimated at the 11th magnitude, from which it increased rapidly and steadily, until it reached the 7th. Its decrease was rather sudden, it being from Nov. 3 to 7 of the 8th magnitude; from the latter date to Nov. 20 there were indications of a marked secondary maximum, the star on the 20th being estimated at $7^{M}.5$. But cloudy and windy weather interfering with observation until Nov. 28, the time of this latter phase could not be ascertained; on the 28th the star was found to have fallen to = DM. +69°.584, or $8^{M}.3$, at which it remained when the last observation was made.

V Herculis. ″ 202

Observations on this star were begun July 11, continuing until Dec. 6, and amounting in number to 56. At the first observation the star was about $5^{M}.2$ in my estimation, rising to a well-marked maximum July 29, when its magnitude was 2 steps > *ρ Herculis*, or $3^{M}.8$. From this time until Aug. 22, only three observations were secured; these indicate a minimum of about $5^{M}.2$ at the latter date, after which it rose, with several minor fluctuations, to a maximum of about $3^{M}.9$ on or about Sept. 20; the indicated curve being here so flat as to make it difficult to place definitely the time of maximum. From Oct. 3 to 18, the star's light was nearly stationary at $4^{M}.2$, after which time it increased to a rather slightly indicated maximum of about the 4th magnitude Oct. 30, falling to a minimum of the 5th magnitude Nov. 11; since which time it has risen, at first sharply, then more gradually, until at the last observation the star's light was about = 4^{M}.

R Scuti.

When first observed, June 11, the magnitude of *R Scuti* was, by estimation, $6^{M}.2$; it increased by the 17th to about $5^{M}.6$, at which brightness it remained nearly stationary until July 12, when it slowly increased, showing a faintly-marked maximum July 24, at which date its magnitude was about $5^{M}.4$; it then decreased sharply to a pretty well indicated minimum of about 6^{M} on Aug. 6; increased again quite rapidly till Aug. 23, when a maximum was reached at the 5th magnitude. Another marked minimum at $6^{M}.25$ occurred Sept. 29, followed by a maximum of 5th magnitude Nov. 4; since then the star has steadily declined until Dec. 6, when it was about $5^{M}.8$. At this date observations were discontinued on account of the growing moon and nearness of the star to the sun. In all 71 observations were obtained.

η Aquilae. 7124

Of this star a series of 54 observations was obtained, extending from June 11 to Oct. 25. Eleven maxima and twelve minima were obtained from the observations, all, with the exception of the last five minima, by the use of Pogson's method with the single light-curves. The observed times, with their weights on a scale of 5, are as follows:

Maxima	p	Minima	p
1888 June 12.48	4	1888 June 17.08	4
27.4	4	July 7.25	4.5
July 4.0	4	14.85	4.5
10.55	4	23.2	4
18.05	4.5	Aug. 27.38	4
25.26	3.5	Sept. 2.45	4
Aug. 25.33	2	11.1	4
30.25	4	24.3	1
Sept. 6.0	4	Oct 3.33	1
28.3	4.5	10.3	1
Oct. 20.6	4	17.33	1
		25.3	1

The last five minima are indicated by single observations at a light-value near that of the average minimum, all at the beginning and end of single light-curves, with the exception of that on Oct. 10.3, which is followed by a single observation on the 11th, showing an increase in light; a nominal weight merely has been assigned them.

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S Sagittae.

From ninety-one observations of this star, extending from May 20 to Dec. 2, twelve maxima and thirteen minima are deduced by the use of POGSON's method; the observed times are as follows:

Maxima		p	Minima		p
1888 June	4.4	5	1888 June	2.4	2
July	8.45	4		10.25	5
	16.7	2		18.5	5
	24.4	3		27.25	4
1888 Aug.	28.45	4	1888 July	4.0	3.5
Sept.	5.33	3.5		12.25	3.5
	30.0	3		30.4	1
Oct.	18.4	4	Aug.	24.38	3
	24.25	3	Sept.	9.9	3.5
Nov.	2.4	3		27.4	3
	12.4	4	Oct.	20.25	3
	19.25	2.5		30.0	1
			Nov.	17.1	3

Dorchester, Mass., 1888 *December* 10.

ELLIPTIC ELEMENTS AND EPHEMERIS OF COMET *f* 1888,

BY REV. GEORGE M. SEARLE.

On December 13, I obtained an observation of this comet, using as a comparison-star *Arg. Gen. Cat.* 14378 = *Lal.* 20443; the comet preceding by $59^s.1$, and being south 1′ 52″, Dec. 13, $22^h\ 16^m$ G.M.T. The comparison of my elements, published in the last number of this Journal, with this observation showing a discordance of nearly 1′, I computed a new set from the first and third observations used for the former ones, together with that of Dec. 13. They are as follows:

$$\begin{aligned} T &= \text{Sept. } 12.9983 \text{ G.M.T.} \\ \Omega &= 137^\circ\ 35'\ 16'' \\ i &= 56\ \ 26\ \ 43 \\ \omega &= 291\ \ \ 4\ \ 22 \\ \log q &= 0.185718 \end{aligned} \quad \left.\begin{matrix}\\ \\ \\ \end{matrix}\right\}\text{Equinox 1888.0}$$

These were obtained from the first hypothesis for log ν, and gave $B_t = -0.00695$, apparently indicating a hyperbolic orbit, corresponding to a positive O—C in λ. This value, being rather small, was neglected; but, comparison of the orbit with the middle place giving $\Delta\lambda = +26''$, $\Delta\beta = -2''$, it seemed worth while to try the values of B_t and B_t resulting from another value of u used in the trial, as a change of log ν would apparently produce little effect. The values obtained were $B_t = +0.00612$, $B_t = +0.00385$, giving for the coincidence $B_t = B_t = +0.00290$. The value of u interpolated to correspond gave $B_t = +0.00288$, and the following elements:

$$\begin{aligned} T &= \text{Sept. } 12.5709 \text{ G.M.T.} \\ \Omega &= 137^\circ\ 29'\ 15'' \\ i &= 56\ \ 15\ \ \ 6 \\ \omega &= 290\ \ 28\ \ 46 \\ \log q &= 0.182303 \\ \varphi &= 80^\circ\ 39'\ 50'' \end{aligned} \quad \left.\begin{matrix}\\ \\ \\ \end{matrix}\right\}\text{Equinox 1888.0}$$

Period, 1231 years.

Residuals for the middle place, O—C:

$$\Delta\lambda = -1'' \quad , \quad \Delta\beta = -2''$$

The mean of the residuals for the two observations made on Nov. 11, at Washington and Lick, gives, for the parabola, $\Delta\lambda = +15''$, $\Delta\beta = -4''$; for the ellipse, $\Delta\lambda = -4''$, $\Delta\beta = -5''$. As the ellipse represents the place of Nov. 21, while the parabola gives $\Delta\lambda = +26''$ for that date, the probability of the former is considerable.

The following are the equatorial coordinate equations for the parabola, for 1889.0:

$$\begin{aligned} x &= [9.917607]\, r \sin[v + 174^\circ\ 17'\ 36''] \\ y &= [9.972553]\, r \sin[v + 69\ \ 51\ \ 17\ ] \\ z &= [9.818988]\, r \sin[v + 315\ \ \ 5\ \ 53\ ] \end{aligned}$$

For the ellipse they are,

$$\begin{aligned} x &= [9.917675]\, r \sin[v + 173^\circ\ 30'\ \ 6''] \\ y &= [9.973109]\, r \sin[v + 69\ \ 13\ \ 46\ ] \\ z &= [9.817751]\, r \sin[v + 314\ \ 37\ \ 36\ ] \end{aligned}$$

The following ephemeris has been computed, for Greenwich midnight, from the parabolic formulas, the places being referred to the mean equinox of 1889.0.

Date		α	δ	log Δ	Brightn.
		h m s	° ′		
Jan.	1	10 26 53	+ 3 12.5	0.1520	0.96
	2	26 33	3 42.7		
	3	26 10	4 13.2		
	4	25 46	4 44.0		
	5	25 20	5 15.1	0.1481	0.94
	6	24 52	5 46.5		
	7	24 22	6 18.3		
	8	23 49	6 50.7		
	9	23 14	7 23.5	0.1454	0.92
	10	22 38	7 56.8		
	11	22 0	8 29.3		
	12	21 20	9 2.5		
	13	20 38	9 35.9	0.1442	0.90
	14	19 54	10 9.5		
	15	19 8	10 43.3		
	16	18 21	11 17.2		
	17	17 32	11 51.1	0.1446	0.87
	18	16 42	12 25.2		
	19	15 50	12 59.3		
	20	14 56	13 33.3		
	21	10 14 2	+14 7.4	0.1467	0.83

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The unit of brightness is that of the Lick observation of Nov. 1.

The following corrections will reduce this ephemeris to that resulting from the ellipse:

		$\Delta\alpha$ s	$\Delta\delta$ ′
Jan.	1	— 6	+0.8
	5	— 7	+1.0
	9	— 9	+1.4
	13	—11	+1.8
	17	—13	+2.0
	21	—16	+2.4

New York, 1888 *December* 25.

This ephemeris will be continued in the next number, as the comet will be easily visible in large telescopes for a considerable time. On March 1 the brightness will be 0.38.

The mean of two observations by Prof. Boss, Jan. 3, is represented by the parabolic ephemeris, as follows:

$$(O—C) \quad \Delta\alpha = -1^s.4 \qquad \Delta\delta = +17''$$

For the ellipse the discordance is decidedly larger. S.

NOTE ON THE PROBLEM OF ALIGNMENT,

By A. Hall.

It has been pointed out to me that Bessel, in an article in Bode's *Jahrbuch*, 1821, p. 170, employed the formula which I have used for the solution of this question; *Astr. Jour.*, No. 186. See also Engelmann's *Abhandlungen von Bessel*, Band I, p. 316. Bessel introduces several auxiliary quantities for easing the computation, and first determines $\tan[\alpha-\frac{1}{2}(s-w+\sigma-w')]$, where w and w' are auxiliaries. Mr. G. W. Hill suggests that it might be better to solve for $\tan\delta \sin\alpha$, and $\tan\delta \cos\alpha$.

1888 *December* 24.

NOTE ON THE EQUATION OF THE MERIDIAN TRANSIT INSTRUMENT,

By S. C. Chandler.

In addition to Mayer's, Bessel's and Hansen's formulas, and also that of Gauss, which has escaped notice in the textbooks, a fifth form of this equation occurred to me several years ago, which may be worth a few lines of space in the Journal, as it affords a very brief and clear method for the exposition of the subject to students, and may also, from its simplicity, find advantageous practical applications.

If the line joining the pivots of a transit instrument be not exactly east and west, a line perpendicular to it will describe a great circle in the heavens intersecting the meridian at a small angle, which we will call i. Let D be the declination of the node of the instrumental circle where it passes the meridian from west to east. Then, for the declination δ the distance of the two circles will be $i\sin(\delta-D)$, and the distance of the line of collimation from the true meridian will be $i\sin(\delta-D)+c$, or, in hour-angle, this quantity multiplied by $\sec\delta$. Consequently we have

$$\alpha = t + \Delta t + [i\sin(\delta-D)+c]\sec\delta \tag{1}$$

which is the new form of the equation in question.

The constants in this formula have another geometrical signification than that described above. The eye being supposed to be placed at the east pivot, and the plane of projection being the meridian of the west pivot, i is the apparent angular distance of the projection of the west pivot from that of the true west point, and D is the corresponding position-angle, reckoned from the north through the zenith. Hence we have the relations,

$$m = -i\sin D \qquad n = i\cos D \tag{2}$$

Introducing this value of n into (1), we have still another form,

$$\alpha = t + \Delta t + n(\tan\delta-\tan D) + c\sec\delta \tag{3}$$

which, while resembling Hansen's equation, is shorter by a term, inasmuch as $b\sec\varphi$ is included in $\tan D$.

This equation, with the first of (2), reduces to Bessel's form

$$\alpha = t + \Delta t + m + n\tan\delta + c\sec\delta$$

By simple transformation the last term of (1) becomes

$$i\cos D\tan\delta - i\sin D + c\sec\delta =$$

$$\frac{c+i\cos D}{2}(\sec\delta+\tan\delta) + \frac{c-i\cos D}{2}(\sec\delta-\tan\delta) - i\sin D$$

Then by (2) and the relations

$$\tan\tfrac{1}{2}p = \sec\delta - \tan\delta \quad ; \quad \cot\tfrac{1}{2}p = \sec\delta + \tan\delta$$

where p is the polar distance of the star, and also by putting, for brevity, $C=\frac{1}{2}(c+n)$, and $T=\frac{1}{2}(c-n)$ equation (1) is converted to

$$\alpha = t + \Delta t + m + C\cot\tfrac{1}{2}p + T\tan\tfrac{1}{2}p$$

which is Gauss's form.

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ELEMENTS OF COMET *f* 1888 (*BARNARD*),

BY WILLIAM C. WINLOCK.

[Communicated by Capt. R. L. PHYTHIAN, Supt. U.S. Naval Observatory.]

The elements of this comet, published in No. 185 of the Journal, are affected by an error in the position used for Nov. 1, due to errors in the observations of that date, as originally published. I have, therefore, redetermined the orbit from normal places of Nov. 1 (eight observations), and Nov. 11 (two observations), and single Washington observations of Nov. 21, Dec. 1 and 13.

The most probable parabolic elements, from these five positions, are:

$$T = 1888 \text{ Sept. } 12.91547 \text{ Greenw. M.T.}$$
$$\left.\begin{aligned} \omega &= 290^\circ\ 53'\ 10'' \\ \Omega &= 137\ \ 35\ \ 51 \\ i &= \ \ 56\ \ 21\ \ 17 \end{aligned}\right\} 1888.0$$
$$\log q = 0.184750$$

giving the residuals (O—C) for the several dates.

	$\Delta\lambda \cos\beta$	$\Delta\beta$
	$''$	$''$
Nov. 1	0.0	0.0
11	+ 1.8	— 5.0
21	+ 8.3	— 4.4
Dec. 1	+15.3	—15.6
13	0.0	0.0

The heliocentric rectangular coordinates referred to the mean equator and equinox of 1888.0 are as follows:

$$x = [0.102550] \sec^2\tfrac{1}{2}v \sin(v+174^\circ\ \ 2'\ 54''.4)$$
$$y = [0.157500] \sec^2\tfrac{1}{2}v \sin(v+\ 69\ \ 41\ \ 11\ .6)$$
$$z = [0.003035] \sec^2\tfrac{1}{2}v \sin(v+314\ \ 57\ \ 18\ .4)$$

When referred to 1889.0, they become

$$x = [0.102603] \sin^2\tfrac{1}{2}v \sin(v+174^\circ\ \ 3'\ 35''.2)$$
$$y = [0.157478] \sin^2\tfrac{1}{2}v \sin(v+\ 69\ \ 41\ \ 51\ .2)$$
$$z = [0.002992] \sin^2\tfrac{1}{2}v \sin(v+314\ \ 57\ \ \ 2\ .6)$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1889	α	δ	log r	log Δ	Br.
	h m s	° ′			
Jan. 9	10 23 13	+ 7 22.4	0.3435	0.1452	0.92
11	21 58	8 28.1			
13	20 36	9 31.6	3506	1440	90
15	19 7	10 41.9			
17	17 30	11 49.6	3577	1444	87
19	15 48	12 57.6			
21	13 59	14 5.7	3647	1466	83
23	12 5	15 13.6			
25	10 5	16 21.1	3717	1506	79
27	8 1	17 27.9			
29	5 54	18 33.8	3785	1564	75
31	3 45	19 38.6			
Feb. 2	10 1 30	20 42.2	3854	1640	70
4	9 59 15	21 44.2			
6	56 59	22 44.5	3921	1734	65
8	54 43	23 43.0			
10	52 27	24 39.5	3988	1844	60
12	50 12	25 33.9			
14	47 59	26 26.1	4054	1968	55
16	45 48	27 16.0			
18	43 40	28 3.7	4120	2104	50
20	41 35	28 49.1			
22	39 35	29 32.1	4184	2250	45
24	37 40	30 12.8			
26	35 49	30 51.2	0.4248	0.2404	0.41
28	9 34 4	+31 27.3			

Brightness on November 1 = 1.

Washington, 1888 *Dec.* 27.

ECLIPSE OF THE SUN 1889 JANUARY 1.

The following observations of the time of first contact were made at the Naval Observatory:

Observer.	Instrument.	Washington M.T. of first contact.
		h m s
WINLOCK	9.6-inch equatorial, power 132	4 28 32.8
TUTTLE	Sextant telescope, 12-inch focus, power 16	4 28 32.3

NOTES.

WINLOCK. Time recorded on chronograph. Sun about 2° above horizon, limb "boiling." Actual contact probably took place a second earlier, but owing to the unsteadiness of the limb, I could not have made the record with confidence an instant sooner.

TUTTLE. Time from mean-time chronometer.

R. L. PHYTHIAN, *Superintendent.*

Washington, 1889 *January* 2.

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FILAR-MICROMETER OBSERVATIONS OF COMET e 1888 (*BARNARD*),

MADE AT THE HAVERFORD COLLEGE OBSERVATORY,

BY F. P. LEAVENWORTH AND H. V. GUMMERE.

1888 Haverford M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
d h m s			m s	' "	h m s	° ' "	s	"	
Oct. 3 15 57 34	1	10 , 10	+2 6.57	—1 21.4	6 36 24.11	+8 13 42.0	n9.304	0.675	L
9 16 15 28	2	10 , 9	+1 9.11	—0 5.1	6 28 1.75	+7 24 45.6	n9.041	0.678	L
17 17 13 42	3	4 , 3	+2 25.96	—0 33.8	6 12 8.00	+6 5 31.7	9.000	0.692	G
28 14 3 49	4	13 , 9	—0 3.87	—3 39.7	5 38 47.57	+3 43 19.7	n9.099	0.718	L
Nov. 1 12 26 36	5	4 , -	—4 18.23		5 22 23.64		n9.376		L

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ' "	"	
1	6 34 16.04	+1.50	+8 15 3.0	+0.4	Weisse's Bessel VI, 979
2	6 26 50.93	+1.71	+7 24 50.1	+0.6	Harv. X, No. 59
3	6 9 40.01	+2.03	+6 6 3.9	+1.6	Schjellerup 2109
4	5 38 49.17	+2.27	+3 46 56.7	+2.7	½(W.B. V, 950+Σ.788)
5	5 26 39.30	+2.57			Paris 6404 and Albany 1790

The places of comparison-stars 1, 3 and 4 were kindly furnished by Mr. A. S. FLINT. No. 5 was taken directly from *Astronomical Journal*, No. 185.

EPHEMERIS OF COMET e 1888 (*BARNARD*),

BY LEWIS BOSS.

[Continued from No. 186.]

1889 Gr. M.T.	App. α	App. δ	log r	log Δ	Light
	h m s	° '			
Jan. 28	23 47 38	—5 24.6	0.2589	0.3727	3.2
29	23 47 4	5 19.9	0.2588	0.3762	
30	23 46 32	5 15.2	0.2588	0.3796	
31	23 46 2	5 10.5	0.2588	0.3829	
Feb. 1	23 45 33	5 5.8	0.2588	0.3862	3.0
2	23 45 6	5 1.1	0.2588	0.3894	
3	23 44 40	4 56.3	0.2589	0.3925	
4	23 44 15	4 51.6	0.2589	0.3955	
5	23 43 50	4 46.8	0.2590	0.3985	2.9
6	23 43 27	4 42.1	0.2592	0.4014	
7	23 43 5	4 37.3	0.2593	0.4042	
8	23 42 45	4 32.5	0.2595	0.4070	
9	23 42 25	4 27.7	0.2597	0.4098	2.7
10	23 42 6	4 23.0	0.2599	0.4124	
11	23 41 48	4 18.2	0.2602	0.4149	
12	23 41 31	4 13.4	0.2604	0.4173	
13	23 41 14	4 8.6	0.2607	0.4196	2.6
14	23 40 58	4 3.8	0.2610	0.4219	
15	23 40 44	3 59.0	0.2613	0.4241	
16	23 40 30	3 54.2	0.2616	0.4263	
17	23 40 17	3 49.4	0.2620	0.4284	2.5
18	23 40 4	3 44.6	0.2624	0.4305	
19	23 39 51	—3 39.8	0.2628	0.4325	
Feb. 20	23 39 39	—3 35.0	0.2632	0.4344	
21	23 39 28	3 30.2	0.2636	6.4362	2.4
22	23 39 18	3 25.4	0.2640	0.4379	
23	23 39 8	3 20.6	0.2645	0.4396	
24	23 38 58	3 15.8	0.2650	0.4413	
25	23 38 49	3 11.0	0.2655	0.4429	2.3
26	23 38 40	3 6.2	0.2661	0.4445	
27	23 38 32	3 1.4	0.2666	0.4460	
28	23 38 24	2 56.6	0.2672	0.4474	
Mar. 1	23 38 16	—2 51.9	0.2678	0.4487	2.2
	h m s	° '			
Apr. 11	23 32 51	+ 0 15	0.3055	0.4539	1.8
May 1	23 25 18	+ 1 32	0.3305	0.4244	1.8
May 21	23 9 7	+ 2 27	0.3577	0.3764	2.0
June 10	22 38 0	+ 2 37	0.3856	0.3161	2.3
June 30	21 45 15	+ 1 26	0.4136	0.2626	2.6
Aug. 1	19 52 33	— 3 36	0.4570	0.2762	2.0
Sept. 1	18 39 50	— 8 6	0.4966	0.4008	1.0
Oct. 1	18 15 18	—10 40	0.5323	0.5244	.5

The observed correction for the ephemeris on January 3 was: $\Delta\alpha + 5^s$; $\Delta\delta + 0'.6$.

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OBSERVATIONS OF COMETS,

MADE AT U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

[Communicated by the Superintendent.]

1888–89 Wash. M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
				Comet *e* (Barnard).					
d h m s			m s	′ ″	h m s	° ′ ″			
Dec. 4 9 2 16.1	1	20 , 6	−4 39.20	+4 44.2	1 57 18.59	−6 48 53.0	n7.858	0.800	F
11 9 52 8.5	2	17 , 4	+2 31.00	−0 0.5	1 21 16.10	−7 29 51.0	9.350	0.758	F
20 7 17 47.7	3	20 , 4	+1 2.15	+2 53.5	0 47 18.33	−7 40 59.1	8.780	0.805	F
24 9 23 23.9	4	20 , 4	−1 34.32	−7 48.8	0 35 24.91	−7 36 20.1	9.518	0.787	F
Jan. 10 6 41 19.7	5	24 , 5	−1 14.47	−4 34.9	0 3 28.29	−6 44 12.0	9.362	0.792	F
12 6 43 36.0	5	20 , 4	−3 41.12	+3 35.3	0 1 1.62	−6 36 1.9	9.405	0.789	F
				Comet *f* (Barnard).					
Dec. 1 15 19 28.6	6	40 , 8	+3 6.41	+7 14.6	10 20 16.35	−8 42 40.0	n9.440	0.789	T
4 17 31 17.8	7	20 , 4	−2 58.42	+4 29.8	10 22 21.63	−7 47 57.0	8.085	0.817	T
6 17 8 37.0	8	20 , 4	−1 53.34	−7 29.7	10 23 31.13	−7 11 26.1	n8.230	0.802	T
13 16 14 2.8	9	20 , 4	−0 58.77	−3 6.5	10 26 38.18	−4 50 4.0	n8.897	0.694	T
14 16 43 42.5	10	19 , 4	−1 21.00	−9 26.9	10 26 57.86	−4 37 29.6	n8.028	0.687	T
29 14 44 31.7	11	22 , 5	−0 41.76	−7 12.8	10 27 33.98	+1 54 6.0	n9.118	0.725	W
15 25 49.5	12	20 , 4	+3 33.32	−9 2.1	10 27 33.81	+1 54 53.1	n8.798	0.725	W
Jan. 1 13 51 36.8	13	10 , 2	−3 32.04	+2 8.5	10 26 45.65	+3 21 24.5	9.315	0.712	T
2 11 58 28.4	14	18 , 4	+4 5.55	−3 34.2	10 26 26.12	+3 49 24.2	n9.571	0.720	F
3 11 40 16.6	15	17 , 4	+2 43.87	+3 8.8	10 26 3.67	+4 19 44.9	n9.590	0.719	F
6 15 27 32.4	16	29 , 5	−0 34.33	+2 37.5	10 24 40.05	+5 57 14.9	8.170	0.680	T
11 17 9 21.5	17	20 , 4	−2 21.64	+7 30.3	10 21 39.72	+8 44 15.8	9.409	0.752	T
12 17 38 8.1	18	20 , 4	+1 32.33	−2 27.0	10 20 56.65	+9 18 27.7	9.508	0.667	T

Mean Places for 1888.0 and 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	2 1 55.06	+2.73	−6 53 46.1	+ 8.9	Weisse's Bessel I, 1077
2	1 18 42.61	+2.49	−7 29 59.9	+ 9.4	Weisse's Bessel I, 271
3	0 46 14.12	+2.06	−7 44 2.5	+ 9.9	Lamont 51
4	0 36 57.10	+2.13	−7 28 40.7	+ 9.4	Schjellerup 243
5	0 4 44.07	{−1.31 −1.33}	−6 39 26.3	{−10.8 −10.9}	⅓(Weisse's Bessel+2 Schjellerup)
6	10 17 7.98	+1.96	−8 49 48.0	− 6.6	Schjellerup 3800
7	10 25 18.01	+2.04	−7 52 19.1	− 7.7	Lamont 904
8	10 25 22.36	+2.11	−7 3 48.0	− 8.4	Schjellerup 3850
9	10 27 34.65	+2.30	−4 46 47.0	−10.5	Schjellerup 3863
10	10 28 16.53	+2.33	−4 27 52.0	−10.7	Yarnall 4397
11	10 28 12.89	+2.85	+2 1 33.6	−14.8	½(Weisse's Bessel+Lamont)
12	10 23 57.66	+2.83	+2 4 9.9	−14.7	¼(Weisse's Bessel+Lamont+2 Schjellerup)
13	10 30 17.89	−0.20	+3 19 14.6	+ 1.4	Weisse's Bessel X, 504
14	10 22 20.70	−0.13	+3 52 57.6	+ 0.8	½(Weisse's Bessel+Lamont)
15	10 23 19.91	−0.11	+4 16 35.5	+ 0.6	Bonn VI, +4°, 2342
16	10 25 14.45	−0.07	+5 54 37.7	− 0.3	¼(Weisse's Bessel+Lamont+2 Schjellerup)
17	10 24 1.30	+0.06	+8 36 47.2	− 1.7	½(Weisse's Bessel+Lamont)
18	10 19 24.22	+0.10	+9 20 56.7	− 2.0	⅕(Weisse's Bessel+2 Yarnall+2 Grant)

The observers are Frisby, Tuttle and Winlock. Weisse's position of * 13 is evidently 10s too small; it has been corrected by that amount.

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FILAR-MICROMETER OBSERVATIONS OF COMETS,

MADE AT THE DUDLEY OBSERVATORY,

By LEWIS BOSS.

1888-89 Albany M.T.	*	No. Comp.	☄—* $\Delta\alpha$	☄—* $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			Comet *e* 1888.					
Dec. 12 8h 36m 18s	1	21 , 7	−1m 39s.06	−2′ 58″.2	1h 17m 6s.08	−7° 32′ 46″.2	8s.958	0″.829
12 9 5 30	2	15 , 5	−2 12.64	+1 7.5	1 17 0.53	−7 32 50.6	9.157	0.827
Jan. 3 6 18 42	3	15 , 5	+1 23.13	+ 47.7	0 13 56	−7 10	9.340	0.821
3 6 43 22	4	15 , 5	−3 26.46	−5 12.3	0 13 53.06	−7 10 5.0	9.412	0.818
			Comet *f* 1888.					
Dec. 12 17 20 2	5	21 , 7	−4 33.32	+4 47.4	10 26 17.92	−5 10 35.9	8.656	0.815
Jan. 3 13 33 24	6	15 , 5	+2 42.28	+5 5.8	10 26 1.56	+4 21 36.7	n9.326	0.741
3 14 17 13	7	18 , 6	+4 22.70	−2 24.4	10 26 0.65	+4 22 25.5	n9.132	0.739

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	1h 18m 42s.67	+2s.47	−7° 29′ 57″.2	+9″.2	Gould, G.C. 1330
2	1 19 10.70	+2.47	−7 34 7.3	+ 9.2	Micr. Comp. with Gould 1330
3	0 12 31	+1.90	−7 11	+ 9.5	SDM. −7° 35
4	0 17 17.59	+1.93	−7 5 2.1	+ 9.4	Schjellerup 122
5	10 30 48.98	+2.26	−5 15 13.1	−10.2	Schjellerup 3878–9
6	10 23 17.02	+2.26	+4 16 48.6	−17.7	Albany 4054
7	10 21 35.68	+2.27	+4 25 7.6	−17.7	Albany 4044

Note. — The air was very steady on January 3, but the presence of a very light fog rendered the comparisons for comet *f* somewhat difficult; comet *e* under illumination appears like the diffuse image of a star somewhat brighter than the ninth magnitude.

NEW ASTEROID.

A planet of the twelfth magnitude was discovered by Palisa at Vienna, January 4. Its position was

1889 Jan. 4.3595 Greenw. M.T. $\alpha = 4^h\ 13^m\ 38^s.6$ $\delta = +18°\ 58'\ 15''$

The motion is similar to that of *Siwa*, no. 140, and it is possible that the two planets are identical.

If, as now supposed, the asteroid of Oct. 29 was no. 280, and that of Oct. 31 no. 281,—this of Jan. 4 will be no. 282, should it not prove to be a rediscovery of no. 140. G.

NEW DISCUSSION OF WINNECKE'S COMET.

Die Bahn des periodischen Kometen Winnecke, in den Jahren 1858–1886, *nebst einer neuen Bestimmung der Jupitersmasse*, *von* Dr. Eduard, Freiherrn von Haerdtl. Vienna, 1888.

This valuable contribution to cometology, reprinted from the Memoirs of the Imperial Academy of Sciences, at Vienna, is of especial importance, apart from the minute accuracy with which it follows the path of Winnecke's comet since 1858. A statement of the chief points is given, by the author, in no. 2873 of the *Astronomische Nachrichten*. The memoir contains elaborate discussions of the observations and the resulting elements for the apparitions, 1858 II, 1869 I, 1875 II, and 1886 VI; as well as a summary of our knowledge concerning its former appearances 1819 III, 1808 I, and probably 1766 II.

The comet may attain an aphelion-distance of 5.57, the mean distance of *Jupiter* being 5.20; and their respective

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periods are such that close approaches occur at intervals of about 11 years. Two such approaches took place during the period here discussed, between May 1858, and November 1886; the distance of the comet from *Jupiter* having been 0.87 in December 1870, and only 0.44 in November 1881. The perturbations during these five revolutions have been computed for twenty-day intervals through the corresponding twenty-eight and a half years, and for intervals yet shorter, — even down to five days, — when circumstances seemed to require it. Dr. VON HAERDTL thus finds that they had produced during that time an increase of not less than ninety-five mean days in the period of revolution, as well as large changes in the other elements of the orbit; so that

$$\Delta i = +3^\circ\ 44', \quad \Delta \Omega = -9^\circ\ 51' \text{ and } \Delta\varphi = -2^\circ\ 27'.$$

The perturbations by the other planets have been computed with equal care, excepting for *Mercury* and *Uranus*, the influence of which would be practically inappreciable, since the comet's orbit which, as has been said, scarcely extends beyond that of *Jupiter*, does not at perihelion ($q = 0.831$) even reach that of *Venus*.

One of the very interesting results of this investigation is the evidence that no unexplained acceleration of the mean motion exists, such as ENCKE believed that he had found for the comet which bears his name. On the contrary, Dr. VON HAERDTL found indications of a decided retardation; which disappeared, however, when a new value for the mass of *Jupiter* was introduced.

In short, the author has arrived at the result that a decided modification of the adopted mass of *Jupiter* is required for satisfying the observations; so that, instead of the assumed value 1 : 1047.54, with which he began his computations, he has been led to the adoption of a new value 1 : 1047.1752, — the mean error of the denominator being given as ±0.0136. Introducing this new mass into the computations of FAYE's comet, in the stead of that used by MÖLLER, and found by Dr. VON HAERDTL to be absolutely incompatible with the motion of WINNECKE's, — the results seem to him to indicate that no such incompatibility exists in the former case.

Regarding ENCKE's comet, a similar inference is drawn, so far as the present state of BACKLUND's computations permits.

G.

COMET a 1889.

A rather faint comet was discovered by Mr. BROOKS at Geneva, N.Y., on the morning of January 15, in the position,

1889 Jan. 14.9665 Greenw. M.T. $\alpha = 18^h\ 4^m$ $\delta = -21^\circ\ 20'$

The motion is given as rapid and westerly. The weather has not yet permitted its subsequent observation.

NOTICE.

Mr. JOHN TATLOCK, Jr., (care of North River Safe Deposit Co., 187 Greenwich St., New York), requests that those astronomers who secured observations of the occultations of *Alpha Tauri* by the moon, between the dates of Sept. 10, 1884, and March 18, 1888, inclusive, will kindly send to him copies of the records of such observations, together with full particulars essential to the reduction thereof.

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THE

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ON THE COMPUTATION OF THE TRUE ANOMALY, RADIUS-VECTOR AND COORDINATES IN ELLIPSES OF GREAT ECCENTRICITY,

By Rev. GEORGE M. SEARLE.

After the appearance of the very ingenious and accurate method of computing the anomaly and radius-vector in ellipses nearly approaching the parabola, given by Oppolzer, it may seem superfluous, to say the least, to propose any other solution of the same problem. Still, as I have found the following one practically convenient in the cases most likely to occur, it may be well to give it for what it is worth.

We start with the equation of integration, put in the following form:

$$\frac{k\sqrt{1+e}}{2q^{3/2}}\,t = (\tau+\tfrac{1}{3}\tau^3) - 2\,\varepsilon(\tfrac{1}{3}\tau^3+\tfrac{1}{5}\tau^5) + 3\,\varepsilon^2(\tfrac{1}{5}\tau^5+\tfrac{1}{7}\tau^7) \quad \text{\&c.}$$

in which $\tau = \tan\frac{1}{2}v$ and $\varepsilon = \dfrac{1-e}{1+e}$

If now we denote $\tau + \frac{1}{3}\tau^3$ by nM, n being an arbitrary constant, and make

$$\frac{\tau^3+\frac{3}{5}\tau^5}{(\tau+\frac{1}{3}\tau^3)^3} = A, \qquad \frac{\tau^5+\frac{5}{7}\tau^7}{(\tau+\frac{1}{3}\tau^3)^5} = B, \text{ \&c.}$$

this becomes

$$\frac{k\sqrt{1+e}}{2q^{3/2}}\,t = nM - \tfrac{2}{3}\,A\,n^3M^3\varepsilon + \tfrac{3}{5}\,B\,n^5M^5\varepsilon^2 \text{ \&c.}$$

Now giving to M the value $\dfrac{\sqrt{2}}{k}\,(\tau+\frac{1}{3}\tau^3)$, as used in Oppolzer's table, n becomes $\dfrac{k}{\sqrt{2}}$; dividing the equation by this, and denoting $\dfrac{\sqrt{1+e}}{\sqrt{2}\,q^{3/2}}$ by N, we have

$$Nt = M - \tfrac{2}{3}\,n^2\,\varepsilon\,AM^3 + \tfrac{3}{5}\,n^4\,\varepsilon^2\,.\,BM^5 \text{ \&c.}$$

Now the functions A, B, &c., are readily tabulated for M or log M as an argument; the formulas most convenient for the purpose being perhaps

$$A = \frac{\tau^3(\frac{5}{3}+\tau^2)}{M^3}\,.\,\tfrac{3}{5}\,n^{-3} \qquad B = \frac{\tau^5(\frac{7}{5}+\tau^2)}{M^5}\,.\,\tfrac{5}{7}\,n^{-5}, \text{ \&c.}$$

The logarithm of n is 8.0850664; that of $\frac{3}{5}n^{-3}$, 5.522952; that of $\frac{5}{7}n^{-5}$, 9.42854; that of $\frac{2}{3}n^2$, 5.9940416; that of $\frac{3}{5}n^4$, 2.118417.

Tables being computed of A and B, we do not have to use the table by which v is obtained from M until the value of M has been accurately determined.

For ordinary cases it is quite enough to compute log A to five places, and log B to four; the differences are made more convenient by tabulating log AM, or log AM^2, and using these instead of log A in the higher parts of the table; or log BM, &c., similarly.

The following table has been computed:

M	log A	log B	log M	log A	log B	log M	log A	log B	log M	log A	log B
0	0.00000	0.0000	0.90	9.99839	9.9962	1.04	9.99694	9.9927	1.18	9.99423	9.9863
1	9.99997	9.9999	91	99831	9960	05	99680	9924	19	99397	9857
2	99990	9997	92	99823	9958	06	99665	9920	20	99369	9850
3	99977	9994	93	99815	9956	07	99650	9917	21	99340	9843
4	99959	9990	94	99806	9954	08	99634	9913	22	99310	9836
5	99936	9985	95	99797	9952	09	99616	9909	23	99278	9829
6	99908	9978	96	99787	9949	10	99598	9905	24	99245	9821
7	99875	9970	97	99778	9947	11	99580	9900	25	99210	9813
log M			98	99768	9945	12	99561	9896	26	99174	9804
0.85	99872	9969	0.99	99757	9942	13	99540	9891	27	99136	9795
86	99866	9968	1.00	99745	9939	14	99519	9886	28	99097	9786
87	99860	9966	01	99733	9937	15	99497	9880	29	99056	9776
88	99853	9965	02	99721	9934	16	99473	9875	30	99013	9766
0.89	9.99846	9.9963	1.03	9.99708	9.9931	1.17	9.99449	9.9869	1.31	9.98968	9.9755

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log M	log A	log B	log M	log A	log B	log M	log A	log BM	log M	log AM	log BM^2
1.32	9.98921	9.9744	1.64	9.95790	9.9010	1.95	9.87038	1.6512	2.26	1.95641	3.8383
33	98872	9732	65	95618	8970	96	86619	6518	27	95933	8430
34	98821	9720	66	95440	8929	97	86190	6521	28	96216	8475
35	98768	9708	67	95256	8886	98	85752	6523	29	96491	8519
36	98713	9695	68	95066	8842	1.99	85305	6523	30	96757	8561
37	98655	9681	69	94869	8796	2.00	84848	6521	31	97015	8601
38	98594	9667	70	94666	8749	.01	84381	6517	32	97265	8639
39	98531	9652	71	94455	8701	.02	83905	6511	33	97506	8676
40	98466	9637	72	94238	9.8651	.03	9.83419	6503	34	97739	8712
41	98397	9621			log BM		log AM		35	97965	8746
42	98326	9604	73	94014	1.5899	.04	1.86924	6493	36	98182	8778
43	98252	9586	74	93782	5946	.05	87419	6480	37	98391	8809
44	98175	9568	75	93543	5991	.06	87905	6465	38	98593	8838
45	98094	9549	76	93297	6034	.07	88381	6450	39	98787	8866
46	98010	9529	77	93043	6076	.08	88847	6432	40	98973	8893
47	97923	9509	78	92781	6116	.09	89304	6412	41	99152	8918
48	97832	9487	79	92512	6154	10	89751	6390	42	99324	8941
49	97738	9465	80	92234	6190	11	90189	6366	43	99488	8964
50	97640	9442	81	91948	6225	12	90617	6340	44	99645	8984
51	97538	9418	82	91654	6258	13	91036	6312	45	99794	9004
52	97431	9393	83	91352	6289	14	91445	6283	46	1.99936	9022
53	97321	9367	84	91041	6318	15	91845	6251	47	2.00072	9039
54	97206	9340	85	90722	6345	16	92236	6218	48	00201	9054
55	97087	9312	86	90394	6370	17	92617	6182	49	00322	9068
56	96963	9283	87	90057	6393	18	92989	6145	50	00438	9081
57	96834	9253	88	89712	6415	19	93352	6106	51	00546	9093
58	96701	9222	89	89357	6435	20	93706	6065	52	00648	9104
59	96563	9190	90	88994	6453	21	94051	6023	53	00743	9113
60	96419	9157	91	88621	6469	22	94387	5978	54	00832	9121
61	96270	9122	92	88239	6482	23	94714	5932	55	00915	9128
62	96115	9086	93	87848	6494	24	95032	5884	56	00991	9134
1.63	9.95955	9.9049	1.94	9.87448	1.6504	2.25	1.95341	1.5834	2.57	2.01061	3.9138

We shall seldom need the terms of the series beyond the third; but the fourth may be obtained with very little error by assuming it a third proportional to the second and the third.

The correction necessary to be applied to the fourth term as thus computed will be always additive to its numerical value; and varies from $\frac{11}{189}$ of its computed value for $\tau = 0$ to $\frac{13}{405}$ of it for $\tau = \infty$, falling to a minimum of about $\frac{1}{34}$ for $\tau = 1.986$.

The series, as it has been given, which we may write

$$Nt = M - aA \,.\, M^3 + bB \,.\, M^5 - cC \,.\, M^7, \text{ \&c.}$$

in which $a = [5.9940416]\,\varepsilon$ $b = [2.118417]\,\varepsilon^2$ gives, of course, the time at once from the anomaly; for the inverse problem, we write

$$M = Nt + aA \,.\, M^3 - bB \,.\, M^5 + cC \,.\, M^7 \text{ \&c.}$$

by which M is readily computed with accuracy from an approximate value in most cases, especially in the practical case of an ephemeris, in which the next value of M is approximately given by differences from the preceding ones.

For example, the following are the successive values for several daily intervals in the case of Halley's comet, selected by Gauss and Oppolzer:

Nt	Approx. log M	$a\,AM^3$	$-b\,BM^5$	$c\,CM^7$	sum	M	log M
134.9132	2.13789	+2.5085	—.0538	+0012	+2.4559	137.3691	2.1378891
	730						
137.1415	2.14519	+2.6120	—.0573	+0013	+2.5560	139.6975	2.1451888
	719						
139.3699	2.15238	+2.7176	—.0608	+0014	+2.6582	142.0281	2.1523742
	707						
141.5982	2.15945	+2.8254	—.0646	+0015	+2.7623	144.3605	2.1594485

Three values having been obtained, even at this large value of M, to start with, the next value of log M could evidently be obtained accurately enough by the differences of the series. The last value of log M gives $v = 100° \; 0' \; 0''.1$

The radius-vector is probably most conveniently obtained from the true anomaly by the formula

$$r = \frac{q \sec^2 \frac{1}{2} v}{1 + \varepsilon \ldots}$$

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Another method which seems to have some advantages, especially when we wish, as is usually the case, to obtain the heliocentric coordinates, is as follows.

From the equation $E - e\sin E = kta^{-3/2}$, we readily obtain, developing E in terms of $\sin E$ and dividing by $(1-e)^{3/2}$,

$$\frac{\sin E}{\sqrt{1-e}} + \frac{\sin^3 E}{6(1-e)^{3/2}} + \frac{\sin^3 E}{(1-e)^{3/2}}\left[\tfrac{3}{40}\sin^2 E + \tfrac{5}{112}\sin^4 E \text{ \&c.}\right] = ktq^{-3/2}$$

If now we denote $\dfrac{\sin E}{\sqrt{2(1-e)}}$ by τ, we have

$$\tau + \tfrac{1}{3}\tau^3 + \tau^3\left[\tfrac{3}{20}\sin^2 E + \tfrac{5}{16}\sin^4 E \text{ \&c.}\right] = \frac{k}{\sqrt{2}}q^{-3/2}\,.\,t$$

or, dividing by $\dfrac{k}{\sqrt{2}}$ and making $\sin^2 E = 2(1-e)\tau^2$,

$$\frac{\sqrt{2}}{k}(\tau + \tfrac{1}{3}\tau^3) = q^{-3/2}\,.\,t - mn\,\tau^5$$

in which $m = \dfrac{\sqrt{2}}{k}\,.\,\tfrac{3}{10}(1-e) = [1.392055]\,(1-e)$

and $n = 1 + \tfrac{25}{42}\sin^2 E + \tfrac{175}{432}\sin^4 E + \tfrac{105}{352}\sin^6 E$ &c.

The coefficient of the second term in this series $= \tfrac{5.5}{6.7} \times$ the first coefficient,
That of the third term $= \tfrac{7.7}{8.9} \times$ the second coefficient,
That of the fourth term $= \tfrac{9.9}{10.11} \times$ the third coefficient, &c., &c.

The logarithm of n can easily be tabulated for $\sin^2 E$ as argument. Then τ is readily obtained from the equation above, if we have an approximate value of it, by putting this value in $mn\,\tau^5$, and making $\tau =$ the tangent of one-half the angle corresponding to $q^{-3/2}\,.\,t - mn\,\tau^5$, as M in Oppolzer's form of Barker's table.

This angle, which we may denote by v_0, is not the true anomaly. It has, however, a quite simple relation to it.

We have $r\sin v = a\sqrt{1-e^2}\sin E = q\sqrt{\dfrac{1+e}{1-e}}\sin E = q\sqrt{2(1+e)}\,\tau$

Hence $\tau = \dfrac{p\sin v}{1+e\cos v}\cdot\dfrac{1}{q\sqrt{2(1+e)}} = \dfrac{\sin v}{1+e\cos v}\sqrt{\dfrac{1+e}{2}}$

Or, if we denote $\sqrt{\dfrac{1+e}{2}}$ by η, we have

$$\tau = \frac{\eta\sin v}{1+\cos v-(1-e)\cos v} = \frac{\eta\tan\frac{1}{2}v}{1-\frac{1}{2}(1-e)\cos v\sec^2\frac{1}{2}v}$$

But we do not propose to deduce v from τ or v_0. We have

$$\begin{aligned} r\cos v &= a(\cos E - e) = a(1-e) - 2a\sin^2\tfrac{1}{2}E \\ &= q - 2a\sin^2\tfrac{1}{2}E = q - \tfrac{1}{2}a\sin^2 E\sec^2\tfrac{1}{2}E\,; \end{aligned}$$

and putting in this

$$a\sin^2 E = \frac{2q^2(1+e)\tau^2}{a(1-e^2)} = 2q\,\tau^2$$

from the equation for $r\sin v$ above, we have,

$$\begin{aligned} r\cos v &= q - q\tau^2\sec^2\tfrac{1}{2}E = q - q\tau^2 - q\tau^2\tan^2\tfrac{1}{2}E. \\ &= q\cos v_0\sec^2\tfrac{1}{2}v_0 - q\,\tau^2\tan^2\tfrac{1}{2}E = q\cos v_0\sec^2\tfrac{1}{2}v_0 - q\,\frac{1-e}{2}\,\tau^4\sec^4\tfrac{1}{2}E, \end{aligned}$$

while $r\sin v = \eta\,q\sin v_0\sec^2\frac{1}{2}v_0$. These equations, of course, give v and r, should they be desired; but they can be introduced immediately into the coordinate equations.

The expressions for the coordinates are, if we make

$a\sin A = \cos\Omega$, $a\cos A = -\cos i\sin\Omega$, $b\sin B = \sin\Omega$,
$b\cos B = \cos i\cos\Omega$,

as follows:

$$\begin{aligned} x &= a\cos(A+\omega)r\sin v + a\sin(A+\omega)r\cos v \\ y &= b\cos(B+\omega)r\sin v + b\sin(B+\omega)r\cos v \\ z &= \sin i\cos\omega\,r\sin v + \sin i\sin\omega\,r\cos v \end{aligned}$$

Putting the values of $r\sin v$ and $r\cos v$ just obtained, into these equations, and also making

$$\begin{aligned} a'\sin A' &= qa\sin(A+\omega) & a'\cos A' &= \eta qa\cos(A+\omega) \\ b'\sin B' &= qb\sin(B+\omega) & b'\cos B' &= \eta qb\cos(B+\omega) \\ c'\sin C' &= q\sin i\sin\omega & c'\cos C' &= \eta q\sin i\cos\omega \end{aligned}$$

we have

$$\begin{aligned} x &= a'\sec^2\tfrac{1}{2}v_0\sin(v_0+A') + a''\,\tau^4\sec^4\tfrac{1}{2}E \\ y &= b'\sec^2\tfrac{1}{2}v_0\sin(v_0+B') + b''\,\tau^4\sec^4\tfrac{1}{2}E \\ z &= c'\sec^2\tfrac{1}{2}v_0\sin(v_0+C') + c''\,\tau^4\sec^4\tfrac{1}{2}E \end{aligned}$$

in which a'', b'', c'' are the products of $a'\sin A'$, $b'\sin B'$, and $c'\sin C'$ respectively, by $-\dfrac{1-e}{2}$. They are, of course, small, compared with a', b', and c'; and $\log\sec^4\frac{1}{2}E$ can here be taken $= \frac{1}{2}\log n$, without much error.

The process is practically then as follows:

Compute for the ellipse in question,

$$m = [1.392055]\,(1-e)$$

and

$$\eta = \sqrt{\frac{1+e}{2}}$$

Then assume a value of τ for any date at which we propose to commence our ephemeris; this will be roughly given, of course, should the anomaly not be too large, or the ellipticity too decided, by the formula $M = q^{-3/2}t$, for which value of M we take out v_0 and $\tau = \tan\frac{1}{2}v_0$. After a few dates have been computed, τ or $mn\,\tau^5$ is easily given approximately by differencing. To obtain M accurately, we have

$$M = q^{-3/2}t - mn\,\tau^5$$

for which n is obtained from the table about to be given, the argument $\sin^2 E$ being got by the formula $\sin^2 E = 2(1-e)\tau^2$. The following example will show the practical working of this, the same dates being taken as for the previous process:

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$q^{-3/2}t$	Assumed $mn\,\tau^5$	M	v_0	$\log\tau$	$\sin^2E$	$\log n$	$mn\,\tau^5$
			° ′ ″				
136.0179	1.6209 ${}_{843}$	134.3970	97 30 21.2	0.0570570	0.08415	0.02249	1.6209
138.2645	1.7052 ${}_{867}$	136.5593	98 4 8.4	.0613651	.08584	.02296	1.7052
140.5111	1.7919 ${}_{891}$	138.7192	98 37 8.6	.0655791	.08752	.02342	1.7919
142.7577	1.8810	140.8767	99 9 23.3	0.0697024	0.08920	0.02389	1.8810

A very rough computation (to three or four places) is sufficient for $mn\,\tau^5$ in most cases.

Compute for the ellipse in the case, a, A, b, B, by the formulas $a\sin A = \cos\Omega$, $a\cos A = -\cos i\sin\Omega$, $b\sin B = \sin\Omega$, $b\cos B = \cos i\cos\Omega$, i and Ω, of course, referring to the coordinate planes. These obtain a', A', b', B', c', C', a'', b'', c'', by the equations given above. The coordinates then are computed by the formulas as given.

It may be worthy of notice, that n is about equal to $\sec^5\frac{1}{2}E$. The expression for $\log n$ is

$$\tfrac{100}{21}\log\sec\tfrac{1}{2}E + .002052\sin^4E + .00150\sin^6E + .0011\sin^8E \text{ \&c.}$$

Following is a table for $\log n$.

When $\sin^2E > .1$, $E > 18°\ 26'$, and the original equation $M = E - e\sin E$ can be worked without much difficulty. Still, the table could easily be carried a good deal farther.

TABLE FOR LOG n.

$\sin^2E$	$\log n$	$\sin^2E$	$\log n$	$\sin^2E$	$\log n$	$\sin^2E$	$\log n$	$\sin^2E$	$\log n$
.001	.00026	.021	.00547	.041	.01077	.061	.01615	.081	.02162
2	52	22	574	42	1104	62	1642	82	2189
3	78	23	600	43	1130	63	1669	83	2217
4	104	24	626	44	1157	64	1696	84	2245
5	130	25	652	45	1184	65	1723	85	2272
6	155	26	679	46	1210	66	1751	86	2300
7	181	27	705	47	1237	67	1778	87	2328
8	207	28	732	48	1264	68	1805	88	2355
9	233	29	758	49	1291	69	1832	89	2383
10	259	30	784	50	1318	70	1860	90	2411
11	286	31	811	51	1345	71	1887	91	2439
12	312	32	838	52	1372	72	1914	92	2467
13	338	33	864	53	1399	73	1942	93	2494
14	364	34	890	54	1426	74	1969	94	2522
15	390	35	917	55	1453	75	1997	95	2550
16	416	36	944	56	1480	76	2024	96	2578
17	442	37	970	57	1507	77	2052	97	2606
18	469	38	997	58	1534	78	2079	98	2634
19	495	39	1023	59	1561	79	2107	99	2662
.020	.00521	.040	.01050	.060	.01588	.080	.02134	.100	.02690

INTERPOLATION TABLE.

1	2.6	2.7	2.8
2	5.2	5.4	5.6
3	7.8	8.1	8.4
4	10.4	10.8	11.2
5	13.0	13.5	14.0
6	15.6	16.2	16.8
7	18.2	18.9	19.6
8	20.8	21.6	22.4
9	23.4	24.3	25.2

NEW ASTEROIDS.

A planet of the 13th magnitude, or fainter, was discovered January 28, at Nice. Its position was observed,

1889 Jan. 28.5337 Gr. M.T. $\alpha = 9^h\ 40^m\ 11^s.3$ $\delta = +11°\ 46'\ 33''$

Daily motion, -44^s in α, and 10′ northward.

Another of the 12th magnitude was found February 8, at Nice, in the position,

1889 Feb. 8.3942 Gr. M.T. $\alpha = 9^h\ 40^m\ 52^s.7$ $\delta = +10°\ 19'\ 23''$

Daily motion, -52^s in α and 2′ northward.

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DETERMINATION OF THE ORBIT OF ASTEROID (270) *ANAHITA*,

By W. S. Eichelberger, Student in Johns Hopkins University.

This planet was discovered by Prof. C. H. F. Peters, at Clinton, N.Y., on the evening of Oct. 8, 1887, and was observed during the next five months fifty-eight times, being seen last at Clinton, Mar. 9, 1888.

1. *Preliminary elements.* — As no set of published elements agreed sufficiently well with the observations, the first step taken was to compute new elements. The following elements were computed from four places.

Elements I.

$$
\begin{aligned}
T &= \text{Jan. } 0.1888 \text{ G.M.N.} \\
M &= 60^\circ\ 11'\ 32''.9 \\
\pi &= 332\ \ 22\ \ 54\ .0 \\
\Omega &= 254\ \ 27\ \ 59\ .1 \\
i &= 2\ \ 21\ \ 36\ .2
\end{aligned}
\left.\vphantom{\begin{aligned}\pi\\ \Omega\\ i\end{aligned}}\right\} \text{Mean Equinox and Ecliptic 1888.0}
$$

$$
\begin{aligned}
\varphi &= 8\ \ 37\ \ 8\ .2 \\
\mu &= 1088''.99 \\
\log a &= 0.3419886
\end{aligned}
$$

2. *Correction of elements.* — To correct these elements an ephemeris was computed and compared with the observations. In order to reduce the number of equations of condition, the observations were divided into ten groups. Taking the mean by weights of each of the ten groups of corrections, and considering it applicable to the midnight nearest the mean of the times, the following normal places were derived. They are geometric places, not corrected for aberration, and hold for Greenwich mean midnight.

Date	$\Delta\alpha$	$\Delta\delta$	R.A.	Decl.	W
1887	s	"	h m s	° ' "	
Oct. 12.5	+0.232	+1.38	1 13 19.45	11 59 11.4	7
16.5	+0.263	+0.41	9 31.95	30 22.0	5
20.5	+0.123	+1.18	5 53.60	1 15.1	5
Nov. 1.5	+0.276	+2.30	0 56 50.59	9 39 47.8	6
17.5	+0.288	+0.82	51 19.18	8 25 44.5	1
Dec. 7.5	+0.133	+0.21	56 19.66	9 56.7	5
1888 Jan. 11.5	+0.135	+0.55	1 29 50.42	10 30 54.0	4
Feb. 3.5	—0.050	+0.45	2 2 49.04	13 7 35.2	2
9.5	+0.057	—1.50	12 22.43	51 39.6	3
Mar. 9.5	—0.010	—2.60	3 2 41.21	17 22 34.2	1

That the solution of the equations might give more accurately the correction of the elements, the perturbations of the elements by *Jupiter* were computed and the residuals were corrected by them.

The following perturbations were obtained. Epoch of osculation, Dec. 12.0.

	δi	$\delta\Omega$	$\delta\varphi$	$\delta\pi$	$\delta\mu$	δL
1887	"	"	"	"	"	"
Oct. 13.0	—0.155	+3.478	— 5.666	— 2.258	+0.037	+ 7.054
Nov. 22.0	—0.058	+0.825	— 1.758	+ 0.111	+0.009	+ 2.809
1888 Jan. 1.0	+0.061	—0.816	+ 1.665	— 1.218	—0.006	— 3.125
Feb. 10.0	+0.189	—1.884	+ 4.868	— 7.296	—0.010	— 9.914
Mar. 21.0	+0.318	—2.230	+ 8.156	— 18.165	—0.002	—16.731
1889 Feb. 4.0	+0.775	+4.014	+51.738	—131.297	+0.294	— 2.442
Mar. 16.0	+0.775	+3.985	+58.011	—133.774	+0.337	+12.548

The following are the twenty equations of condition, the first ten arising from the residuals in R.A., the second ten from residuals in Declination.

$\Delta\pi$	$\Delta\Omega$	Δi	$\Delta\varphi$	ΔM_0	$\Delta\mu$		"	W
1.90760	—0.01918	—0.58762	+3.01683	+2.38858	—188.804	=	+4.23	7
1.89602	—0.01978	—0.57794	+3.00411	+2.37200	—188.500		+4.82	5
1.87404	—0.02042	—0.56534	+2.97683	+2.34242	—187.011		+2.82	5
1.75651	—0.02144	—0.51255	+2.82688	+2.18924	—175.848		+5.26	6
1.53759	—0.02142	—0.42169	+2.55186	+1.90495	—149.221		+4.62	1
1.27462	—0.01999	—0.30640	+2.23288	+1.55745	—110.371		+2.23	5
0.97240	—0.01615	—0.14930	+1.87333	+1.13783	— 51.247		+1.85	4
0.86322	—0.01340	—0.07930	+1.73201	+0.97145	— 20.992		—0.55	2
0.84252	—0.01271	—0.06478	+1.70190	+0.93773	— 14.104		+0.90	3
0.77278	—0.00926	—0.01334	+1.57548	+0.81262	+ 16.280		—0.23	1
0.72450	+0.04541	+1.54425	+1.20306	+0.89740	— 61.223		+1.85	7
0.72940	+0.04684	+1.50638	+1.20775	+0.90312	— 62.690		+0.89	5
0.72916	+0.04800	+1.46238	+1.20484	+0.90258	— 63.686		+1.65	5
0.70003	+0.05012	+1.30298	+1.15674	+0.86578	— 63.513		+2.82	6
0.61763	+0.05012	+1.06180	+1.03708	+0.76180	— 56.886		+0.84	1
0.50130	+0.04760	+0.77843	+0.87776	+0.61270	— 43.549		+0.31	5
0.34720	+0.04166	+0.40886	+0.66555	+0.40927	— 20.664		+0.41	4
0.27638	+0.03825	+0.24065	+0.55370	+0.31416	— 9.147		+0.53	2
0.26011	+0.03746	+0.20368	+0.52528	+0.29254	— 6.664		—1.47	3
0.18768	+0.03417	+0.05336	+0.38486	+0.19964	+ 2.176		—2.58	1

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After making the following transformations:

$$1.90495\, \Delta v = 1.90495\, \Delta M_0 + 2.55186\, \Delta\varphi + 1.53759\, \Delta\pi - 149.221\, \Delta\mu$$
$$0.42169\, \Delta\beta = 0.42169\, \Delta i + 0.02142\, \Delta\Omega$$

$$x = \frac{\Delta\varphi}{10}, \quad y = \frac{\Delta\pi}{100}, \quad z = 10\, \Delta\mu, \quad w = \frac{\Delta\Omega}{100}$$

that the formation of the normal equations might be simplified, we obtain the following final forms of our equations of condition.

Δv	x	y	z	$\Delta\beta$	w		W	Resid.
2.39	−1.83	− 2.04	−0.17	−0.59	+1.07	= +4.23″	7	−1.30″
2.37	−1.73	− 1.86	−0.27	−0.58	+0.96	+4.82	5	−0.80
2.34	−1.61	− 1.67	−0.35	−0.57	+0.83	+2.82	5	+1.63
2.19	−1.06	− 1.06	−0.44	−0.51	+0.46	+5.26	6	−0.57
1.90	0.00	0.00	0.00	−0.42	0.00	+4.62	1	−0.47
1.56	+1.46	+ 1.75	+1.16	−0.31	−0.44	+2.23	5	+0.76
1.14	+3.49	+ 5.40	+3.79	−0.15	−0.85	+1.85	4	−1.67
0.97	+4.31	+ 7.91	+5.51	−0.08	−0.94	−0.55	2	+1.05
0.94	+4.46	+ 8.56	+5.94	−0.06	−0.94	+0.90	3	−0.49
0.81	+4.87	+11.69	+7.99	−0.01	−0.86	−0.23	1	+0.30
0.90	+0.01	+ 0.02	+0.91	+1.54	−3.30	+1.85	7	−0.20
0.90	−0.02	+ 0.04	+0.81	+1.50	−2.97	+0.89	5	+0.86
0.90	−0.04	+ 0.06	+0.70	+1.46	−2.63	+1.65	5	+0.19
0.87	−0.03	+ 0.12	+0.43	+1.30	−1.61	+2.82	6	−0.99
0.76	+0.17	+ 0.27	+0.28	+1.06	−0.38	+0.84	1	+0.76
0.61	+0.57	+ 0.68	+0.44	+0.78	+0.81	+0.31	5	+0.59
0.41	+1.19	+ 1.69	+1.14	+0.41	+2.09	+0.41	4	−0 58
0.31	+1.33	+ 2.28	+1.55	+0.24	+2.60	+0.53	2	−1.12
0.29	+1.33	+ 2.40	+1.73	+0.20	+2.71	−1.47	3	+0.82
0.20	+1.17	+ 2.65	+1.86	+0.05	+3.15	−2.58	1	+1.70

From these were obtained the following

Normal Equations.

Δv	x	y	z	$\Delta\beta$	w	
+172.29	− 26.03	+ 7.87	+ 65.36	− 0.34	− 11.63	= +304.48″
− 26.03	+255.58	+418.95	+257.08	+19.79	− 37.07	−109.04
+ 7.87	+418.95	+729.31	+470.33	+23.21	− 51.85	− 99.03
+ 65.36	+257.08	+470.33	+333.06	+27.83	− 61.87	+ 39.20
− 0.34	+ 19.79	+ 23.21	+ 27.83	+61.80	− 89.85	+ 0.52
− 11.63	− 37.07	− 51.85	− 61.87	−89.85	+263.19	− 49.31

The solution of these equations gives

$\log w = 9.45885n$	$\Delta\Omega = -28''.76$
$\log \Delta\beta = 7.45467$	$\Delta i = +1.46$
$\log z = 0.14287n$	$\Delta\mu = -0.1389$
$\log y = 9.98082$	$\Delta\pi = +95.68$
$\log x = 9.62169n$	$\Delta\varphi = -4.19$
$\log \Delta v = 0.33604$	$\Delta M_0 = -80.34$

Applying these corrections, the reduction to 1889.0, and the perturbations, we obtain these elements.

Elements II.

1889 Feb. 24.0 Gr. M.T.

$M = 187°\ 31'\ 45''.8$

$\pi = 332\ \ 23\ \ 7\ .0$
$\Omega = 254\ \ 28\ \ 36\ .3$ } Mean Equinox and Ecliptic 1889.0
$i = 2\ \ 21\ \ 38\ .4$

$\varphi = 8\ \ 37\ \ 58\ .9$

$\mu = 1089''.17$

$\log a = 0.3419406$

from which the following ephemeris was computed.

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1889	α (h m s)	δ (° ′ ″)	log Δ
Feb. 16.5	10 44 57.55	+3 50 20.7	0.191424
17.5	43 59.06	55 40.0	
18.5	42 59.93	+4 1 5.3	
19.5	42 0.23	6 36.4	
20.5	41 0.01	12 12.7	0.188377
21.5	39 59.35	17 54.1	
22.5	38 58.31	23 39.9	
23.5	37 56.98	29 29.7	
24.5	36 55.43	35 23.1	0.186601
25.5	35 53.73	41 19.7	
26.5	34 51.97	47 19.1	
27.5	33 50.21	53 20.7	
28.5	32 48.54	59 24.1	0.186133
Mar. 1.5	31 47.04	+5 5 28.8	
2.5	10 30 45.77	11 34.4	

1889	α (h m s)	δ (° ′ ″)	log Δ
Mar. 3.5	10 29 44.83	+5 17 40.4	
4.5	28 44.28	23 46.4	0.186977
5.5	27 44.23	29 51.7	
6.5	26 44.72	35 56.0	
7.5	25 45.82	41 58.9	
8.5	24 47.60	48 0.0	0.189108
9.5	23 50.14	53 58.7	
10.5	22 53.50	59 54.6	
11.5	21 57.73	+6 5 47.5	
12.5	21 2.90	11 36.8	0.192461
13.5	20 9.10	17 22.1	
14.5	19 16.36	23 3.1	
15.5	18 24.72	28 39.6	
16.5	10 17 34.23	+6 34 11.2	0.196962

Opposition Feb. 25. Mag. 12.1.

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1889.

For remarks and comparison-stars see Vol. VII, p. 187 foll. Also, it should be noted that the times for *Y Cygni* are extremely uncertain, probably by several hours; see Vol. VIII, p. 130.

February	d	h
λ Tauri	9	9
R Canis Maj.	9	19
U Cephei	9	20
U Ophiuchi	9	21
Algol	10	13
U Ophiuchi	10	18
Y Cygni	10	18
S Cancri	10	20
U Coron. Bor.	10	22
δ Librae	11	17
Y Cygni	12	6
U Cephei	12	7
λ Tauri	13	8
Algol	13	10
Y Cygni	13	18
R Canis Maj.	14	9
U Cephei	14	19
U Ophiuchi	14	22
Y Cygni	15	6
R Canis Maj.	15	12
U Ophiuchi	15	18
R Canis Maj.	16	15
Y Cygni	16	18
λ Tauri	17	7
U Cephei	17	7
R Canis Maj.	17	18
U Coron. Bor.	17	19
Y Cygni	18	6
δ Librae	18	17
R Canis Maj.	18	22
Y Cygni	19	18
U Cephei	19	19
U Ophiuchi	19	23
S Cancri	20	7
U Ophiuchi	20	19
Y Cygni	21	6
U Ophiuchi	21	15
U Cephei	22	7
Y Cygni	22	18
R Canis Maj.	23	10
Y Cygni	24	6

February	d	h
R Canis Maj.	24	14
U Coron. Bor.	24	17
U Cephei	24	19
Algol	24	21
δ Librae	25	16
R Canis Maj.	25	17
Y Cygni	25	18
U Ophiuchi	26	16
R Canis Maj.	26	20
U Cephei	27	6
Y Cygni	27	6
Algol	27	18
Y Cygni	28	18

March	d	h
U Cephei	1	18
S Cancri	1	19
Y Cygni	2	6
Algol	2	15
U Ophiuchi	2	20
R Canis Maj.	3	9
U Coron. Bor.	3	15
U Ophiuchi	3	16
Y Cygni	3	18
U Cephei	4	6
R Canis Maj.	4	12
δ Librae	4	16
Y Cygni	5	6
Algol	5	12
R Canis Maj.	5	16
U Cephei	6	18
Y Cygni	6	18
R Canis Maj.	6	19
U Ophiuchi	7	22
Y Cygni	8	6
U Ophiuchi	8	18
U Cephei	9	6
Y Cygni	9	18
Y Cygni	11	6
S Cancri	11	7
R Canis Maj.	11	8

March	d	h
δ Librae	11	15
U Cephei	11	18
R Canis Maj	12	11
Y Cygni	12	18
U Ophiuchi	12	22
R Canis Maj.	13	14
U Ophiuchi	13	19
Y Cygni	14	6
U Ophiuchi	14	15
R Canis Maj.	14	18
Y Cygni	15	18
U Cephei	16	17
Y Cygni	17	6
δ Librae	18	15
Y Cygni	18	18
U Ophiuchi	18	19
R Canis Maj.	19	7
U Ophiuchi	19	15
Algol	19	20
Y Cygni	20	6
R Canis Maj.	20	10
S Cancri	20	18
U Coron. Bor.	20	21
R Canis Maj.	21	13
U Cephei	21	17
Y Cygni	21	18
Algol	22	16
R Canis Maj.	22	16
Y Cygni	23	6
U Ophiuchi	23	19
U Ophiuchi	24	16
Y Cygni	24	18
U Ophiuchi	25	12
Algol	25	13
δ Librae	25	14
Y Cygni	26	6
U Cephei	26	17
Y Cygni	27	18
U Coron. Bor.	27	19
R Canis Maj.	28	9
U Ophiuchi	28	21

March	d	h
Y Cygni	29	6
R Canis Maj.	29	12
U Ophiuchi	29	17
S Cancri	30	6
U Ophiuchi	30	13
R Canis Maj.	30	15
Y Cygni	30	18
U Cephei	31	16

April	d	h
Y Cygni	1	6
δ Librae	1	14
Y Cygni	2	18
U Ophiuchi	2	21
U Coron. Bor.	3	16
U Ophiuchi	3	18
Y Cygni	4	6
U Ophiuchi	4	14
R Canis Maj.	5	8
U Cephei	5	16
Y Cygni	5	18
R Canis Maj.	6	11
Y Cygni	7	6
R Canis Maj.	7	14
U Ophiuchi	7	22
δ Librae	8	14
S Cancri	8	17
Y Cygni	8	18
R Canis Maj.	8	18
U Ophiuchi	8	18
U Ophiuchi	9	14
Y Cygni	10	6
U Coron. Bor.	10	14
U Cephei	10	16
Y Cygni	11	18
Algol	11	18
Y Cygni	13	6
R Canis Maj.	13	7
U Ophiuchi	13	19
R Canis Maj.	14	10
Algol	14	15

April	d	h
U Ophiuchi	14	15
Y Cygni	14	18
U Ophiuchi	15	11
δ Librae	15	13
R Canis Maj.	15	13
U Cephei	15	15
Y Cygni	16	6
R Canis Maj.	16	16
Algol	17	12
U Coron. Bor.	17	12
Y Cygni	17	18
U Ophiuchi	18	20
Y Cygni	19	6
U Ophiuchi	19	16
U Ophiuchi	20	12
U Cephei	20	15
Y Cygni	20	18
R Canis Maj.	21	6
Y Cygni	22	6
R Canis Maj.	22	9
δ Librae	22	13
R Canis Maj.	23	12
Y Cygni	23	18
U Ophiuchi	23	21
U Coron. Bor.	24	10
R Canis Maj.	24	15
U Ophiuchi	24	17
Y Cygni	25	6
U Ophiuchi	25	13
U Cephei	25	15
Y Cygni	26	18
S Cancri	27	17
U Coron. Bor.	27	20
Y Cygni	28	6
U Ophiuchi	28	22
δ Librae	29	12
Y Cygni	29	18
U Ophiuchi	29	18
R Canis Maj.	30	8
U Ophiuchi	30	14
U Cephei	30	14

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SUN-SPOT OBSERVATIONS, OCTOBER 1888 TO FEBRUARY 1889,

By PAUL S. YENDELL.

The following observations are in continuation of those published in No. 183 of this Journal, p. 117, and were made under the same conditions as those.

There was much trouble in November and December with bad atmospheric conditions, and also on account of the situation of the telescope at a window; the latter condition, however, was unavoidable under the circumstances, and the disturbance to definition from this cause much less than had been feared.

Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.
1888	h m			1888	h m			1888	h m			1889	h m		
Oct. 1	22 30	0	0	Oct. 30	20 45	0	0	Nov. 22	21 15	0	0	Jan. 3	22 15	0	0
3	20 30	0	0	31	22 05	0	0	27	21 0	1	4	7	21 15	0	0
4	21 0	0	0					29	21 15	1	7	9	22 0	0	0
7	21 45	0	0	Nov. 1	20 55	0	0					10	21 0	0	0
9	20 30	0	0	2	20 55	0	0	Dec. 2	21 15	1	9	14	21 0	0	0
10	20 25	0	0	4	20 40	0	0	5	21 15	1	3	17	21 45	0	0
14	20 30	0	0	5	22 0	1	8	6	20 45	1	1	20	20 30	0	0
15	22 15	0	0	6	20 45	1	8	9	20 45	0	0	22	20 30	0	0
16	20 45	0	0	11	20 45	2	12	13	21 55	0	0	24	20 30	0	0
17	20 40	0	0	12	20 35	2	5	14	21 15	0	0	27	20 30	0	0
18	20 40	0	0	13	20 45	2	5	20	21 15	1	2	28	20 30	0	0
20	20 45	0	0	15	20 45	2	3	27	21 45	0	0	30	20 45	0	0
24	20 55	0	0	16	20 45	1	1	28	23 0	0	0	31	22 45	0	0
25	20 45	1	2	19	20 45	1	1	31	22 15	0	0				
28	20 55	0	0	20	21 0	1	2								
29	20 55	0	0	21	21 0	1	2								

NOTES.

Oct. 1. Thin cloud. — Oct. 4. Large group of faculae near pr. limb. Image very sharp. — Oct. 7. Just clearing; definition perfect. — Oct. 9 and 10. Air very bad. — Oct. 18. Sky covered with thin cloud; definition tremulous. — Oct. 20. Seeing very bad. — Oct. 25. Near western limb. Seeing rather poor.—Oct. 28. Through thin cloud. — Nov. 1. Air rather bad. — Nov. 2 to 6. Through thin cloud. — Nov. 11. Seeing good. — Nov. 12. Air very tremulous. — Nov. 15. Group of two large spots near pr. limb accompanied by a large and bright facula on the foll. side. — Nov. 20. Seeing poor.— Nov. 21. Close to pr. limb; large and bright facula close foll. — Nov. 22. Short views through driving snow-clouds. — Dec. 2. Seeing poor; more spots might probably have been counted, had the definition been better. — Dec. 5. Seeing very imperfect. — Dec. 6. Seeing bad. — Dec. 13. Seen through thin snow-cloud; image all broken up. — Dec. 14. Seeing poor. — Dec. 20. Seeing leaves much to be desired: spots surrounded by extensive faculae. — Dec. 27. Seeing fair. — Dec. 28. Seeing bad. — Dec. 31. Seeing poor. — 1889 Jan. 17. Definition good. — Jan. 20. Air rather tremulous.— Jan. 24. Seeing good. — Jan. 28. Thin film of snow-cloud; seeing bad. — Jan. 30. Observation through thin cloud; image sharp and steady. — Jan. 31. Seeing good.

Boston, 1889 *January* 31.

CORRIGENDA.

No. 186, p. 141, col. 2, for *ξ Piscium* put *ζ Piscium*.
No. 187, p. 145, col. 1, for *U Herculis* put *u Herculis*.
" p. 148, col. 1, in rectangular coordinates for 1889.0, for $\sin^2 \frac{1}{2} v$, put $\sec^2 \frac{1}{2} v$.

CONTENTS.

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THE

ASTRONOMICAL JOURNAL.

No. 189.

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CONTRIBUTIONS TO THE KNOWLEDGE OF THE INEQUALITIES IN THE PERIODS OF THE VARIABLE STARS,

BY S. C. CHANDLER.

I.

Since the classical researches of ARGELANDER, which formed such an epoch in the theory of the variable stars, revealing the existence and formulating the laws of the inequalities to which the periods of a few of them are subject, the study of the ever increasing fund of observations has brought to light many more phenomena of the same class. An abstract of our present knowledge of the numerical laws of these perturbations has been given in the introduction to my catalogue. It is proposed, in the following series of articles, to present the original investigations on which were based the elements of that catalogue, with some extensions and improvements since made, for those stars whose irregularities of period were found to be amenable to any reasonably simple mathematical law, and for which the data of observation sufficed for ascertaining the constants certainly enough to give the hypothetical elements any practical value.

2946. *R Cancri*.

The date of the first known maximum of this star I have taken as the mean between the times inferred by ARGELANDER and SCHÖNFELD from SCHWERD's magnitudes in the catalogue to hour VIII of the Berlin charts. The other known maxima comprise eight by ARGELANDER, one by AUWERS, two by SCHÖNFELD, and five by SCHMIDT. Besides, there are six estimates of the magnitude of the star when near maximum in 1852, in the Bonn meridian circle, and six others in 1863 and 1864. Also, POGSON observed it 1856 Feb. 9, "very little less than 6^{M}." But no useful information can be extracted from these data. The star has also been observed in recent years by HARTWIG, WILSING, and the writer, but no times of maxima have been published.

ARGELANDER first noted that the observations were not consistent with the assumption of a uniform period. The elements of SCHÖNFELD's catalogue were based on the observations of 1850–1859. In my own catalogue I have introduced a secular term in the elements, although I do not consider that the question as to the true law is yet free from doubt; for, if we assume only 22 periods to have elapsed between 1830 and 1852, and that the mean period is about 360 days, we have deviations of a character which can be explained by a cyclical term covering about 35 or 40 periods. Thus, I have given in the table two sets of values, O—C, corresponding to two hypotheses as to the elements, viz:

$$(A) \quad 1852 \text{ March } 25.0 + 359.5\ E$$
$$(B) \quad 1852 \text{ April } 21.1 + 352.81\,E + 0.207\,E^2$$

The calculated times of maximum for the next two years are,

	Hypoth. *A*.	Hypoth. *B*.
Epoch 38	1889 Aug. 19	1889 Oct. 30
39	1890 Aug. 13	1890 Nov. 2
40	1891 Aug. 8	1891 Nov. 6

Careful observations within this interval ought to distinguish as to the correct hypothesis. The second is the one that I adopted for the catalogue.

E	Observed Maximum	O—C *A*	O—C *B*	Observer
—23	1830 May 22	—69	0.0	Schwerd
0	1852 Apr. 27	+33	+ 5.9	Argelander
+ 1	1853 Apr. 2	+13.5	— 7.1	"
2	1854 Apr. 10	+27	+12.7	"
3	1855 Mar. 19	+10.5	+ 1.6	"
4	1856 Feb. 28	+ 6	+ 2.3	"
5	1857 Feb. 23	— 1.5	— 0.3	"
6	1858 Feb. 17	— 2	+ 3.6	"
7	1859 Jan. 27	—17.5	— 7.9	"
"	" Jan. 26	—18.5	— 8.9	Auwers
18	1869 Oct. 29 :	—44 :	—17.7 :	Schönfeld
22	1873 Oct. 26	—24	— 4.1	"
26	1877 Nov. 4 :	+ 8 :	+14.9 :	Schmidt
29	1880 Oct. 17.5	+ 8	+ 0.8	"
30	1881 Oct. 31 :	+27 :	+14.3 :	"
31	1882 Oct. 5	+ 6.5	—12.1	"
+32	1883 Oct. 23	+30	+ 5.0	"

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3477. *R Leonis minoris.*

From circumstances analogous to those of the preceding star, there is also here a doubt as to the true law which the decided departures from a uniform period actually obey. Previous to the discovery of variability by SCHÖNFELD, in 1863, there is no known observation back to the time of LALANDE, who, on 1796 March 19, recorded it as 9^{M}. From the neighboring stars in the same zone, SCHÖNFELD infers that this really corresponds to $7^{M}.7$. Now, the maximum magnitude of the star is only exceptionally as faint as $7^{M}.5$; on the average it is brighter than 7^{M}. According to my observations, the increase is very much more rapid than the decrease, at least near maximum. From these facts I conclude that the actual maximum did not occur probably more than 30 days before, or 60 days after, LALANDE's observavation. Comparing with the maximum of 1865, supposing 67 periods to have elapsed, we have a mean period within the limits 374.9–376.2 days; or, with 68 periods, within the limits 369.3–370.6 days. Taking this into connection with subsequent maxima, we are reduced to two hypotheses, namely: (A), a mean period of about 370 days with a periodical fluctuation of moderate amplitude and duration; (B), a successive shortening of the period since LALANDE's time. Therefore, as in the case of the preceding star, I give a comparison of the observed maxima in the accompanying table with two sets of elements, viz:

(A) 1865 Mar. 22.0 + 370.5 E
(B) 1865 Feb. 20.0 + 373.5 E —0.033 E^2

The elements (B) were selected for the catalogue, but I am not at all certain of the correctness of the choice. The calculated times of maxima for the next two years are:

	A	B
Epoch 24	1889 July 26	1889 Aug. 18
25	1890 July 31	1890 Aug. 25
26	1891 Aug. 6	1891 Sept. 1

E	Observed Maximum	O—C A	O—C B	Observer
—68	1796 Mar. 19	—10.0	-	Lalande
—67		-	— 1.4	Lalande
0	1865 Feb. 25	—25.0	+ 5.0	Schönfeld
1	1866 Feb. 23	—34.5	— 7.5	"
2	1867 Mar. 3	—30.0	— 5.9	"
3	1868 Mar. 8	—29.5	— 8.2	"
"	" Mar. 8	—29.5	— 8.2	Winnecke
4	1869 Mar. 13	—30.0	—11.5	Schönfeld
5	1870 Apr. 2	—15.5	+ 0.3	"
6	1871 Apr. 2	—21.0	— 7.8	"
7	1872 Apr. 26	— 1.5	+ 9.1	"
8	1873 May 4	+ 1.0	+ 9.1	"
9	1874 May 14	+ 5.5	+11.2	"
10	1875 May 23	+ 9.0	+12.3	"

E	Observed Maximum	O—C A	O—C B	Observer
10	1875 May 26	+12.0	+15.3	Chandler
14	1879 June 3.6	— 0.4	— 5.9	Schmidt
15	1880 June 21.0	+12.5	+ 4.9	"
"	1881 June 23.3	+14.8	+ 7.2	"
17	1882 June 26.0	+ 6.5	+ 5.0	"
18	1883 June 25 :	0.0	—13.3 :	Chandler
"	" July 2 :	+ 7.0	— 6.3 :	Sawyer
19	1884 July 24 :	+24.5	+ 9.4 :	"
20	1885 June 26	— 9.0	—25.8	"

3825. *R Ursae Majoris.*

In the column of remarks of the catalogue, it was stated that the elements of this star were provisional, the real character of the manifest deviations from uniformity of period being uncertain. The idea of a gradual shortening from discovery to the present time does, indeed, conform tolerably with the observed maxima, as the column "B," of the values (O—C) below, shows. But there is difficulty in reconciling it with some magnitude-estimates in the Radcliffe meridian-circle, made a few years previous to the discovery of variability. These estimates are here given, together with the computed times of maximum, according to two hypotheses as to the elements:

Date of Obs.	Mag.	Computed Maxima Hypoth. A	Hypoth. B
1843 Apr. 25	8	1843 May 19	1843 Feb. 18
27	8.9		
1844 Mar. 15	9	1844 Mar. 17	1843 Dec. 22
20	8.9		
1848 Apr. 1	10	1848 May 2	1848 Mar. 3

The two hypotheses as to the elements are:

(A) 1853 Apr. 7.2 + 302.1 E + 15.0 sin(10° E+190°)
(B) 1853 Mar. 12.5 + 305.4 E — 0.075 E^2

Now, the star attains $9^{M}.5$ about 31 days before maximum, according to SCHÖNFELD; my observations make the interval somewhat greater, but give for $8^{M}.5$ an interval from maximum of not over 20 days, either way. It is thus evident that the Radcliffe estimates are incompatible with (B), but are entirely consonant with (A).

According to hypothesis (A) the epoch —76 occurred 1790 June 4, which falls in well with the fact that LALANDE, on 1790 Mar. 15, did not observe the variable, but did record its neighbor.

In the table below the date 1843 May 15, for epoch —12, is assumed as a maximum by collating all the Radcliffe estimates above given. Comparison with both sets of elements is made. In the next edition of the catalogue I shall adopt the elements (A); and also, for the principal epoch of minimum, 1852 Dec. 21.2, deduced from fourteen minima, the value of the interval from minimum to the succeeding maxi-

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mum being found to be 107 days. The computations were made without the observations of KNOTT and BAXENDELL. After the residuals for these were inserted, it was seen that a slight modification of the constants would improve the results, but it seemed not worth while to repeat the calculation. The above elements give the computed times.

Maxima	Minima
1889 Aug. 13	1889 Apr. 28
1890 June 12	1890 Feb. 25
1891 Apr. 11	1890 Dec. 24
1892 Feb. 28	1891 Oct. 24

E	Observed Maximum	O—C A	O—C B	Observer
—12	1843 May 15?	— 4	+84	Rad. M.C.
+ 2	1854 Nov. 22	— 2.9	+ 9.0	Pogson
3	1855 Sept. 15.5	— 5.4	+ 1.5	"
"	" Sept. 25.5	+ 4.1	+11.0	Schönfeld
"	" Sept. 26.5	+ 5.6	+12.5	Oudemans
4	1856 July 10	— 7.1	— 4.9	Pogson
"	" July 20.5	+ 3.4	+ 5.6	Schönfeld
5	1857 May 15	+ 1.3	— 0.6	Pogson
"	" May 20	+ 6.3	+ 4.4	Schönfeld
"	" May 18	+ 4.3	+ 2.4	Baxendell
6	1858 Mar. 16	+ 5.3	— 0.2	Pogson
"	" Mar. 3	— 7.7	—13.5	Baxendell
7	" Dec. 30	— 7.1	—15.6	Auwers
"	1859 Jan. 5	— 1.1	— 9.6	Pogson
"	" Jan. 16	+ 9.9	+ 1.4	Baxendell
10	1861 June 19	—12.2	—26.0	"
11	1862 Apr. 15	—15.2	—29.8	"
15	1865 Aug. 29.5	+ 1.0	—11.1	Schönfeld
"	" Sept. 8	+10.5	— 1.6	Knott
16	1866 July 4.0	+ 4.8	— 5.7	Schönfeld
"	" July 20	+20.8	+10.3	Knott
17	1867 Apr. 22.5	— 7.4	—16.1	Schönfeld
"	" May 7	+ 7.1	— 1.6	Knott
18	1868 Mar. 13	+13.4	+ 6.6	Schönfeld
"	" Mar. 8	+ 8.4	+ 1.6	Knott
19	" Dec. 26	— 3.3	— 8.0	Dunér
"	1869 Jan. 3	+ 4.7	0.0	Schönfeld
"	" Jan. 14	+15.7	+11.0	Knott
20	" Nov. 3	+ 4.2	+ 1.5	Schönfeld
"	" Nov. 1	+ 2.2	— 0.5	Knott
21	1870 Aug. 28	— 1.9	— 2.8	Schönfeld
22	1871 July 8	+ 8.1	+ 9.0	"
"	" July 7	+ 7.1	+ 8.0	Knott
23	1872 Apr. 29	+ 0.5	+ 3.0	Schönfeld
"	" May 8	+ 9.5	+12.0	Knott
24	1873 Feb. 25	— 0.8	+ 3.1	Schönfeld
25	" Dec. 18	— 7.5	— 2.6	"
26	1874 Oct. 31	+ 7.4	+12.8	"
27	1875 Aug. 26	+ 4.3	+10.4	Chandler
+28	1876 June 17	— 1.2	+ 5.1	Schmidt
+29	1877 Apr. 23	+ 7.9	+14.0	Schmidt
"	" Apr. 6	— 9.1	— 3.0	Knott
30	1878 Jan. 28.2	—12.5	— 6.8	Schmidt
"	" Jan. 27	—13.7	— 8.0	Knott
32	1879 Oct. 1.5	— 1.5	+ 3.0	Schmidt
34	1881 May 22.8	— 1.4	+ 1.4	"
35	1882 Mar. 26.7	+ 7.0	+ 9.1	"
"	" Mar. 24	+ 4.3	+ 6.4	Knott
36	" Dec. 31.7	—12.5	—11.0	Schmidt
37	1883 Nov. 15	+ 6.3	+ 7.4	"
"	" Nov. 20	+11.3	+12.4	Chandler
"	" Nov. 27:	+18.3:	+19.4:	Sawyer
38	1884 Aug. 29	— 5.4	— 4.4	"
"	" Aug. 31	— 3.4	— 2.4	Baxendell, Jr.
39	1885 July 1:	+ 0.5:	+ 2.0:	"
"	" July 1	+ 0.5	+ 2.0	Sawyer
"	" June 28	— 2.5	— 1.0	Knott
40	1886 Apr. 29	+ 2.3	+ 4.5	Sawyer
"	" May 1	+ 4.3	+ 6.5	Baxendell, Jr.
41	1887 Feb. 21	— 0.7	+ 3.2	Knott
+43	1888 Oct. 22	+ 6.3	+14.0	Yendell

E	Minimum	O—C A	O—C B	Observer
7	1858 Sept. 15.9	— 9.2	—11.2	Pogson
15	1865 Apr. 28	—19.6	—25.1	Knott
16	1866 Mar. 18	— 0.2	— 4.2	"
17	1867 Jan. 11	— 5.9	— 8.1	"
18	" Nov. 21	+ 3.4	+ 3.1	"
19	1868 Sept. 17	— 0.2	+ 1.5	"
20	1869 July 19	+ 0.3	+ 4.0	"
22	1871 Mar. 17	— 1.9	+ 5.5	"
30	1877 Oct. 13	—16.7	— 4.5	"
39	1885 Mar. 10	— 9.5	— 1.5	"
"	" Mar. 23	+ 3.5	+11.5	Baxendell, Jr.
40	" Dec. 29	—15.7	— 7.0	"
41	1886 Nov. 20	+ 9.3	+19.7	"
42	1887 Sept. 13	+ 4.5	+17.5	"

3994. *S Leonis.*

Since the elements inserted in my catalogue were determined, a review of the subject, in the light of data later acquired, leads me to believe that we can with advantage substitute a periodical term for the secular one. This conforms better to WINNECKE's maximum of 1859 — which I was formerly inclined too much to distrust, perhaps — and also to two maxima, not very satisfactory ones, observed by me in 1883.

From the magnitude estimate, 9.10, of a meridian-circle observation by PALISA (*A.N.* 2221), epoch 1878.17, the star must have been quite near maximum at that time, and it appears allowable, in view of the paucity of recent data, to employ this in the table of observed maxima below.

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The elements 1860 Dec. 1 + 190 E + 25 sin$(10°E+60°)$, a comparison with which is shown in the column (O—C), afford a tolerable representation of this series. They give for the computed times of the next few maxima,

Epoch 55	1889 June	18
56	Dec.	24
57	1890 July	2
58	1891 Jan.	8
59	July	18

E	Observed Max.	O—C	Observer
— 3	1859 May 16	— 7.5	Winnecke
0	1860 Dec. 24	+ 1.4	"
+ 8	1865 Feb. 5.5	— 8.6	Schönfeld
10	1866 Feb. 21.0	— 0.5	"
12	1867 Mar. 3.5	+ 3.5	"
14	1868 Mar. 13.5	+ 7.9	"
16	1869 Mar. 21	+ 8.1	"
18	1870 Mar. 16	— 6.3	"
20	1871 Apr. 9	+ 5.6	"
22	1872 Apr. 18	+ 0.6	"
26	1874 May 20	— 5.9	"
28	1875 June 2+	— ?	"
33	1878 Mar. 3 :	+18.5 :	Palisa
43	1883 Apr. 15 :	—19.1 :	Chandler
44	1883 Nov. 12 :	+ 4.9 :	"

4521. *R Virginis.*

The period of this star has been investigated by ARGELANDER, (*A.N.* 40, pp. 361 foll.), and also by SCHÖNFELD, (*A.N.* 69, p. 252, and 78, p. 135). The former derived an inequality covering about 98 periods; but in the light of subsequent observations, both the duration and the amplitude of the irregularity appear to have been very much understated. SCHÖNFELD, however, made no attempt to represent the systematic deviations from a uniform period by a formula, but noted merely that neither a simple periodical term, nor one depending on the square of the time, would suffice for the purpose. With the lapse of time the prospect of success in the attempt to establish the constants of a more complex formula is naturally greater, and I have felt warranted in undertaking the investigation, the results of which are here presented.

In addition to the 48 maxima and 14 minima collected by SCHÖNFELD in the places above quoted — including ARGELANDER's Ep. 125 (*A.N.* 73, p. 12) — we have the following 33 maxima and 14 minima since observed.

By combining these observations in groups, normal epochs were formed, as indicated in the first four columns of the accompanying table. The discussion gave, after various approximations, the following elements:

$$\left.\begin{array}{l}\text{Max. 1809 June } 0.8\\ \text{Min. 1809 Mar. } 24.3\end{array}\right\} + 145.47\,E + 20.0\sin(\tfrac{9}{5}{}^{\circ}E + 216°) + 4.8\sin(\tfrac{4\frac{1}{2}}{8}{}^{\circ}E + 343°)$$

E	Maxima	Observer	E	Maxima	Observer
148	68 May 28.5	Schönf.	172	77 Nov. 30	Schwab
150	69 Mar. 19	"	173	78 Apr. 28.8	"
152	70 Jan. 8	"	"	May 3.2	Schmidt
153	May 31.5	"	175	79 Feb. 9.6	"
155	71 Mar. 8	"	178	80 Apr. 21.5	"
156	Aug. 8.2	Schmidt	181	81 June 29.5	Schmidt
158	72 June 1	"	183	82 Apr 16.6	"
160	73 Feb. 27	Schönf.	186	83 June 21.0	"
161	July 27	Schmidt	"	June 20.0	Sawyer
163	74 May 8	"	187	Nov. 18	Chandler
"	May 11	Schönf.	188	84 Apr. 11.0	Sawyer
165	75 Feb. 17	Schönf.	191	85 June 13	"
166	July 18	Schmidt	193	86 Apr. 8	"
168	76 Apr. 23	Schwab	"	Apr. 9	Gore
"	Apr. 23.5	Schmidt	196	87 June 17 :	Sawyer
170	77 Feb. 17.5	Schwab	198	88 Mar. 31	Yendell
171	July 11.6	Schmidt			

E	Minima	Observer	E	Minima	Observer
156	71 May 28	Schönf.	166	75 May 5	Schönf.
"	June 1	Schmidt	171	77 May 2	Schmidt
158	72 Mar. 24	"	173	78 Feb. 26.2	"
"	Mar. 16	Schönf.	176	79 Apr. 29.5	"
159	Aug. 5	Schmidt	179	80 July 9	"
161	73 May 13 :	"	181	81 Apr. 19.5	"
163	74 Feb. 25	Schönf.	184	82 June 30.5	"

The deviations of the observed normal epochs from the first two terms of this expression — *i.e.*, from a uniform period — are given in the column O—C′; then follow the values of the first periodical term in the sixth column; the subtraction of these from O—C′ forms the column O—C″; then come the values of the second periodical term, which, subtracted from O—C″, give finally the outstanding differences, O—C, in the last column. The comparison of each sine-term with the column of residuals immediately preceding it, will, I think, establish confidence in the formula, as an approximate expression, at least, of the variations in the period. That the second sine-term effects a very material improvement is shown by the reduction of the sum of the squares of the residuals from 213.9 to 55.8 for the maxima, and from 95.0 to 52.0 for the minima. It should be stated that the mean value of the period and the law of its inequalities were deduced entirely from the maxima; and therefore the highly satisfactory manner in which they conform to the minima, as shown in the table, is strongly confirmatory of the law assumed; and, further, is evidence that the inequalities in question pertain to the period and not to the light-curve.

I infer that the outstanding deviations, O—C, are only in small part due to errors of observation, but are mainly the effect of errors of assumption in regard to the law or its constants, or of failure of the phenomenon itself to conform strictly to an exact law. For we find, from seven maxima common to two observers, that the probable error of a single observation of maximum is $\pm 1^{d}.7$, and hence, for a mean of five, $\pm 0^{d}.7$; while from the column O—C the probable deviation of a normal epoch, resting on five maxima, is $\pm 1^{d}.8$.

The present elements place the maximum epoch —33 on

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1796 March 27, thus within eleven days of the date when LALANDE overlooked the star, in his zone of 1796 April 7, the circumstances of which have been fully discussed by ARGELANDER (*B.B.* VI, 381). But the actual observations now cover so large a range in time, that the fact of the omission possesses little significance at this late day.

TABLE OF NORMAL EPOCHS.

Group	Mean Epoch	No. Obs.	Observed Normal Epoch	O—C′	First Sine Term	O—C″	Second Term	O—C
			MAXIMA.					
0– 7	4	5	1810 Dec. 21.1	—13.6	—13.7	+0.1	+0.5	—0.4
10– 20	15	5	1815 May 9.3	—13.5	—17.8	+4.3	+4.4	—0.1
22– 37	29	5	1820 Dec. 1.1	—17.3	—20.0	+2.7	+2.7	0.0
40– 50	45	5	1827 Apr. 12.9	—21.0	—17.8	—3.2	—4.0	+0.8
52– 58	55	5	1831 Apr. 11.9	—15.7	—14.1	—1.6	—4.4	+2.8
88– 98	94	5	1846 Nov. 19.5	+11.5	+ 8.5	+3.0	+2.3	+0.7
100–110	106	5	1851 Aug. 30.0	+10.4	+14.6	—4.2	—3.0	—1.2
112–120	116	5	1855 Aug. 26.3	+13.0	+18.1	—5.1	—4.8	—0.3
123–130	126	5	1859 Aug. 26.1	+19.1	+19.8	—0.7	—2.3	+1.6
140–150	145	5	1867 Mar. 22.4	+20.5	+17.8	+2.7	+4.7	—2.0
152–158	155	5	1871 Mar. 17.1	+21.5	+14.1	+7.4	+3.4	+4.0
160–166	163	6	1874 May 8.7	+ 6.3	+10.2	—3.9	0.0	—3.9
168–173	171	7	1877 July 9.9	+ 0.7	+ 5.6	—4.9	—3.4	—1.5
175–183	179	4	1880 Sept. 12.6	— 2.3	+ 0.6	—2.9	—4.8	+1.9
186–188	187	4	1883 Nov. 15.2	— 7.5	— 4.4	—3.1	—3.4	+0.3
191–198	194	5	1886 Aug. 26.8	—10.2	— 8.5	—1.7	—0.5	—1.2
			MINIMA.					
45– 53	49	3	1828 June 1.4	—18.9	—16.5	—2.4	—4.7	+2.3
118–128	124	5	1858 Aug. 28.0	+15.4	+19.6	—4.2	—3.1	—1.1
141–148	145	4	1867 Jan. 10.3	+17.9	+17.8	+0.1	+4.7	—4.6
151–156	154	4	1870 Aug. 12.0	+18.3	+14.6	+3.7	+3.9	—0.2
158–161	159	4	1872 Aug. 7.9	+17.9	+12.3	+5.6	+1.9	+3.7
163–173	168	4	1876 Feb. 23.2	+ 2.9	+ 7.4	—4.5	—2.3	—2.3
176–184	180	4	1880 Nov. 28.4	— 2.5	0.0	—2.5	—4.9	+2.4

The elements of my catalogue were adopted as mere provisional substitutes, pending the completion of the above investigation, whose results will supplant them in the next edition.

The new elements furnish the computed times of both phases during the next two years, as follows:

Epoch	Maximum	Minimum
201	1889 June 10	1889 Apr. 3
202	Nov. 3	Aug. 26
203	1890 Mar. 28	1890 Jan. 19
204	Aug. 20	June 13
205	1891 Jan. 13	Nov. 5
206	June 7	1891 Mar. 30
207	Oct. 30	Aug. 23

4557. *S Ursae Majoris.*

The light-curve of this star near maximum is unusually flat, and frequently affected by irregularities which still further increase the difficulty of assigning the true instant of maximum phase. Consequently the minima are much more suitable for determining the period, and have been exclusively used for this purpose by SCHÖNFELD. On the contrary, the observed maxima are much more numerous, and cover a wider range in time. I have employed both phases.

A cursory inspection of the observations from discovery down, shows a distinct general lengthening of the period, at an average rate of 0.204 days for each recurrence; whence the term $0.102\,E^2$ which I inserted in the catalogue, from a discussion of the maxima between 1855 and 1886. A closer examination of the series extended in one direction by three maxima whose times I have inferred from some meridian-circle estimates of magnitude at the Radcliffe Observatory in 1843, 1844 and 1849, and in the other by observations in 1887 and 1888 which have since come to hand, points to a modulation of the rate of lengthening, requiring a formula of sines. The period of the principal inequality, having scarcely run through its cycle, is quite uncertain; but is apparently about 72 periods of the star.

In the accompanying table of maxima and minima the values O—C correspond to the elements,

$$\left.\begin{matrix}\text{Max. 1860 June 11.0}\\ \text{Min. 1860 Feb. 24.5}\end{matrix}\right\} + 226.5\,E$$

The deviations for both phases manifestly follow the same law. A term $+40.0\,\sin(5°E+205°)$ secures an approxi-

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mate representation of them, but leaves residuals outstanding which may be largely disposed of by a still further term, $+13 \sin(8°E+36°)$. But it seems best to rest satisfied with the above elements, including only the first sine term, until a few more years of observation have developed the irregularity further. The clew afforded by the estimate of 9^{M} by LALANDE, 1790 Mar. 7, is now of little value, as the true date of maximum to which it corresponds may be 50 or 60 days on either side, for the reasons given at the beginning of this article. The uniform period above gives for Ep. —113 the value O—C = —18.5.

Using only the first inequality, with the 40-day coefficient, the calculated times of the next few phases are:

Epoch	Maxima	Minima
47	1889 Sept. 15	1889 May 29
48	1890 Apr. 27	1890 Jan. 9
49	Dec. 9	Aug. 24
50	1891 July 24	1891 Apr. 7
51	1892 Mar. 6	Nov. 19

The initials of observers in the table are: Au for AUWERS, Bx for J. BAXENDELL (italics for the father, roman for the son), Ch for CHANDLER, Dr for DUNÉR, Kn for KNOTT, P for POGSON, Sd for SCHÖNFELD, Sm for SCHMIDT, Sr for SAWYER, Yn for YENDELL, and RO for Radcliffe Observatory.

E	Maxima	O—C	Obs.	*E*	Maxima	O—C	Obs.
—28	43 Apr. 11	+71.0	RO	— 2	59 Mar. 2	—14.0	Au
27	44 June 1:	+35.0:	"	— 1	Oct. 15	—13.5	"
18	49 May 23	+40.0	"	+ 1	61 Jan. 21	— 2.5	*Bx*
8	55 June 17	— 9.0	P	6	64 Feb. 5	—25.0	"
"	July 7.5	+11.5	Sd	8	65 May 1	—27.0	Sd
7	56 Feb. 11	+ 3.5	P	9	Dec. 22	—18.5	"
6	Sept. 24.5	+ 3.5	Sd	"	Dec. 28	—12.5	Kn
"	Sept. 14	— 7.0	P	10	66 Aug. 16	— 7.0	"
5	57 May 5.5	0.0	Sd	"	Aug. 12	—12.0	Sd
3	58 July 25	+ 2.5	*Bx*	+11	67 Mar. 8	—30.5	"

E	Maxima	O—C	Obs.	*E*	Maxima	O—C	Obs.
+11	67 Mar. 2	—36.5	Kn	+31	79 Sept. 2	+ 0.5	Sm
12	Oct. 19	—32.0	"	32	80 Apr. 20.8	+ 5.8	"
13	68 June 5	—28.5	"	33	Dec. 7.8	+10.3	"
"	June 3	—30.5	Sd	34	81 July 27.3	+15.3	"
14	69 Jan. 7	—39.0	Dr	35	82 Mar. 13	+17.5	"
"	Jan. 14	—32.0	Sd	"	Mar. 1	+ 5.5	Kn
"	Jan. 12	—34.0	Kn	36	Nov. 1	+24.0	Sm
15	July 18	—73.5	"	37	83 June 6	+14.5	Ch
"	July 30	—61.5	Sd	"	June 14	+22.5	Sm
16	70 Mar. 3	—72.0	"	"	June 16	+24.5	Sr
17	Nov. 29	—27.5	"	38	84 Jan. 18	+14.0	Ch
18	71 July 19	—22.0	"	39	Sept. 17	+30.5	Sr
"	June 30	—41.0	Kn	"	Sept. 20	+33.5	Bx
19	72 Mar. 1	—22.5	Sd	40	85 May 5	+34.0	Kn
20	Oct. 7	—29.0	"	"	May 7	+36.0	Sr
21	73 May 11	—39.5	"	"	May 7	+36.0	Bx
22	Dec. 4	—58.0	"	41	Dec. 25	+41.5	"
23	74 Aug. 23	—23.5	"	"	Dec. 25	+41.5	Kn
24	75 Mar. 24	—37.0	"	42	86 Aug. 10	+43.0	"
27	77 Mar. 5	— 4.5	Kn	43	87 Mar. 13	+31.5	"
28	Sept. 26	—26.0	"	44	Nov. 1:	+38.0	"
+29	78 May 7	—29.5	"	+45	88 June 16	+39.5	Yn

E	Minima	O—C	Obs.	*E*	Minima	O—C	Obs.
— 7	55 Oct. 24	+ 1.0	P	+17	70 Aug. 2	—39.0	Sd
— 6	56 June 14	+ 8.5	"	18	71 Mar. 17	—38.5	"
— 3	58 Apr. 30	+14.0	*Bx*	"	Mar. 19	—36.5	Kn
+ 2	61 May 19	— 3.5	"	19	Nov. 1	—36.0	Sd
9	65 Sept. 1	—23.0	Sd	20	72 June 16	—34.5	"
"	Sept. 5	—19.0	Kn	21	73 Jan. 28	—35.0	"
10	66 Apr. 7	—31.5	"	23	74 Apr. 24	—37.0	"
"	Apr. 9	—29.5	Sd	24	Nov. 25	—48.5	"
11	Nov. 24	—27.0	"	28	77 June 22	—14.5	Kn
"	Nov. 26	—25.0	Kn	38	83 Oct. 4	+15.5	Ch
12	67 July 13	—22.5	"	40	85 Jan. 16	+32.5	Bx
"	July 7	—28.5	Sd	41	Aug. 28	+30.0	"
13	68 Feb. 12	—35.0	Kn	"	Aug. 30	+32.0	Kn
14	Oct. 3	—27.5	"	43	86 Dec. 2	+38.0	"
15	69 May 11	—34.0	Sd	"	Dec. 8	+44.0	Bx
16	Dec. 16	—41.5	"	+44	87 July 11	+32.5	Kn
+ "	Dec. 26	—31.5	Kn				

OBSERVED MAXIMUM OF *U ORIONIS*,

BY PAUL S. YENDELL.

From 1888 November 30, to 1889 February 3, I obtained a series of thirty-eight observations of *U Orionis*.

At the first mentioned date, the star's light was estimated to be 1 step > DM. 20°1156, equivalent to about $7^{M}.1$; it increased steadily and rather quickly until December 18, when it was 4 steps < DM. 19°1126, or $6^{M}.4$, at which brightness, with some fluctuations, to be hereafter noted, it remained until 1889 January 7 or 8. From this date it declined, rather more slowly than it had increased, until at the last observation of the series, 1889 February 3, its brightness was about the same as at the first.

Dorchester, Mass., 1889 *February* 18.

A general light-curve, drawn after a careful consideration and weighing of the observations, assigns 1888 December 27.5 for date of maximum. This, however, is not the date of the greatest observed light; between December 22 and 25, the observations indicate a rise of about 0.2 of a magnitude, followed December 27 by a very sharp and sudden fall of quite half a magnitude; this observation was carefully made, and fully confirmed by another, taken about five hours later on the same evening. On December 29 it was again observed at its average maximum brightness.

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A COMPARISON OF THE POSITIONS OF STARS IN *PRAESEPE* DERIVED BY DR. B. A. GOULD FROM PHOTOGRAPHS, WITH THE POSITIONS OBSERVED BY PROFESSOR A. HALL, U.S.N.

By Ensign H. S. CHASE, U.S.N.

[Communicated by Capt. R. L. Phythian, U.S.N., Superintendent of Naval Observatory.]

Dr. Gould's positions are published in the *Memoirs of the National Academy of Sciences*, Vol. IV, Part I, and Professor Hall's in the *Washington Astronomical and Meteorological Observations*, 1867, Vol. XIV, Appendix IV. Dr. Gould's positions are deduced from measurements of photographs made by Mr. Rutherfurd. Professor Hall's positions depend on filar-micrometer measurements with a 9½-inch equatorial, and have been brought forward to the epoch of Dr. Gould's positions by means of the coefficients of precession given in Professor Hall's catalogue.

Gould	Hall	Gould	Hall		Gould	Hall	
No.	No.	α	α	G—H	δ	δ	G—H
		h m s	h m s	s	° ′ ″	° ′ ″	″
1	23	8 29 58.13	8 29 58.09	+0.04	20 11 37.8	20 11 37.3	+ 0.5
2	26	30 2.38	30 2.37	+0.01	19 58 46.4	19 58 47.8	— 1.4
3	29	9.12	9.12	0.00	43 43.0	43 43.7	— 0.7
4	43	58.50	58.44	+0.06	20 27 11.0	20 27 11.8	— 0.8
5	49	31 24.24	31 24.27	—0.03	27 50.4	27 52.1	— 1.7
6	52	27.62	27.62	0.00	8 29.0	8 29.1	— 0.1
7	53	30.91	30.86	+0.05	3 25.5	3 25.4	+ 0.1
8	61	32 3.32	32 3.25	+0.07	33 7.4	33 9.5	— 2.1
9	62	4.00	4.00	0.00	14 40.0	14 41.2	— 1.2
10	63	7.38	7.36	+0.02	19 44 29.2	19 44 29.9	— 0.7
11	65	12.69	12.64	+0.05	20 0 25.9	20 0 27.6	— 1.7
12	68	18.48	18.45	+0.03	2 57.0	1 11.3	(+105.7)
13	71	19.77	19.77	0.00	0 29.4	0 31.0	— 1.6
14	78	27.21	27.20	+0.01	28 28.5	28 30.1	— 1.6
15	81	32.36	32.32	+0.04	26 17.6	26 18.4	— 0.8
16	91	44.77	44.78	—0.01	18 9.3	18 11.4	— 2.1
17	93	47.14	46.98	(+0.16)	38 58.8	39 0.4	— 1.6
18	86	40.19	40.20	—0.01	19 59 58.1	19 59 59.2	— 1.1
19	88	42.72	42.74	—0.02	49 0.0	49 2.4	— 2.4
20	87	42.43	42.49	—0.06	20 9 15.5	20 9 15.9	— 0.4
21	90	43.82	43.85	—0.03	8 15.4	8 15.4	0.0
22	96	49.07	49.09	—0.02	0 45.7	0 47.4	— 1.7
23	98	56.03	56.01	+0.02	19 39 44.0	19 39 46.5	— 2.5
24	100	33 2.16	33 2.19	—0.03	41 43.4	41 49.4	(— 6.0)
25	102	4.85	4.87	—0.02	20 11 15.7	20 11 16.5	— 0.8
26	107	18.34	18.38	—0.04	2 57.6	2 59.2	— 1.6
27	112	35.00	34.98	+0.02	23 29.5	23 31.8	— 2.3
28	113	41.33	41.38	—0.05	19 43 51.4	19 43 53.5	— 2.1
29	127	34 13.85	34 13.79	+0.06	20 37 49.4	20 37 51.9	— 2.5
30	126	11.53	11.54	—0.01	20 42.6	20 45.0	— 2.4
31	131	8 34 29.18	8 34 29.18	0.00	19 52 59.0	19 53 1.9	— 2.9

Rejecting the numbers inclosed in parentheses, which seem to be due to errors of observation or reduction,

$$\Delta\alpha = +0^s.005 \pm 0^s.004, \qquad \Delta\delta = -1''.39 \pm 0''.11;$$

the probable error of a single difference in right-ascension is $\pm 0^s.023$, and in declination, $\pm 0''.60$.

1889 *February* 26.

TOTAL SOLAR ECLIPSE OF 1889 JANUARY 1.

Prof. Hall, Home Secretary of the National Academy of Sciences, transmits the following observations, sent him by Mr. J. S. Torrence, B.S., College City, California.

They were made with a telescope of two inches aperture, and in mean time of the 120th meridian west of Greenwich.

	h m s	
First contact,	0 26 41	p.m.
Beginning of totality,	1 51 30	"
End of totality,	1 52 50	"
Last contact,	3 10 2	"

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CORRECTIONS TO THE LICK OBSERVATORY TIME-SIGNALS FOR DEC. 30.0, DEC. 31.0, JAN. 1.0 AND JAN. 2.0,

BY J. M. SCHAEBERLE, ASTRONOMER OF THE LICK OBSERVATORY.

The following corrections to the time-signals sent from this Observatory are published for the benefit of those observers of the last solar eclipse who desire to obtain more accurate data.

The corrections to the standard sidereal clock were obtained on the evenings of Dec. 29, 30, 31, Jan. 1 and Jan. 2.

1889 *January* 7.

Date		Corrections to reduce to Pacific Standard Time
	d	s
1888	Dec. 30.00	+0.98
1888	Dec. 31.00	+0.35
1889	Jan. 1.00	—0.18
1889	Jan. 2.00	+0.01

ON A SEARCH FOR THE COMET REPORTED 1889 JAN. 15, BY MR. BROOKS,

BY E. E. BARNARD, ASTRONOMER OF THE LICK OBSERVATORY.

BROOKS's comet, reported to have been discovered January 15, has been searched for here, but without success, on the following mornings, January 17 and 18, being cloudy. The dates refer to the civil day.

January 19. Very slight haziness. $\delta = -19°$ to $-25°$ $\alpha = 17^h\ 45^m$ to S.E. horizon at 6^h.

January 20. Sky good. —17° to —26°; $17^h\ 45^m$ to S.E. horizon at $6^h\ 15^m$.

January 21. Cloudy.

January 23. Covered the same regions as on 20th until 6^h.

January 25. —17° to —26°; $17^h\ 40^m$ to $18^h\ 00^m$, until 6^h. Frequent fog.

January 26. —16° to —27°; $16^h\ 50^m$ to S.E. horizon, until 6^h.

January 28. —14° to —30°; $16^h\ 15^m$ to $18^h\ 10^m$, until $6^h\ 15^m$.

January 29. —15° to —30°; $17^h\ 30^m$ to $18^h\ 0^m$, until 6^h.

January 30. —15° to —37°; $15^h\ 30^m$ to $16^h\ 20^m$, until 6^h.

February 3. —15° to —40°; $14^h\ 00^m$ to $16^h\ 30^m$, until 6^h.

These surveys were carefully made with the 12-inch equatorial, with a field of 42′, power 80 diameters; the recorded declinations being for the centre of the field. No nebulous object was seen that could not be identified in N.G.C. Up to the last three mornings the moon interfered, more or less, with the search.

On the morning of January 28, Dr. SWIFT, who was then on a visit to the Observatory, searched thoroughly for the comet with the 4-inch broken-tube comet seeker, but found nothing that was not identifiable, covering all the S.E. sky. He also subsequently covered the same region on several mornings.

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THE

ASTRONOMICAL JOURNAL.

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SOME OBSERVATIONS OF VARIABLE STARS IN 1888,

BY EDWIN F. SAWYER.

1. *g Herculis.*

The observations on this star number 35, and extend from April 2 to November 3.

The light-fluctuations during the year have been of a less decided character than has been the case for some years past; the extreme range being not over half a magnitude. The observations, however, when charted, permit the certain determination of 2 maxima and 1 minimum. From April 2, the date of the first observation, up to May 16, a period of 44 days, the brightness remained apparently constant. The series is, however, much broken between these dates, and notably from April 2 to 13 and from April 16 to May 6. From May 16 to June 1, the brightness rapidly increased, and a faint maximum was passed on June 3. The decrease after June 5, although slight, was sudden; and the light remained stationary until August 25, a period of 75 days. The minimum was passed about July 18. A slight increase took place after August 25, and a second and faint maximum was reached on September 11. The interval between the two maxima was thus 100 days. The light suddenly fell after September 24, and remained constant until the observations terminated, November 3.

2. *R Scuti.*

44 observations of this star were obtained; extending from June 1 to December 6. Breaks occur in the series from September 5 to 24, October 8 to 24, and November 7 to December 6. The fluctuations in light during the year were not of a very decided character, and only 2 maxima and 1 minimum are certainly shown. From June 1 to August 4, a period of 64 days, the light appeared sensibly constant. After August 4, the star slowly brightened; and a rather bright maximum was passed on August 30. Light = 20.0. The light rapidly declined after September 2, and a bright minimum was reached on October 1. Light = 13.5. After a rapid rise a second maximum was passed on November 7. Light = 20.2. The interval between the 2 maxima 69 days.

3. *R Lyrae.*

A very fair series of observations (34 in number) was obtained on this star, extending from June 1 to November 8. From these observations 6 well determined maxima and minima have been obtained, as follows: Maxima, July 27, September 5 and October 22: Minima, July 6, August 13 and September 29. The interval between the first and second maxima was 40 days, and between the second and third maxima, 48 days. Between the first and second minima the interval is 38 days; and between the second and third minima, 47 days. All the maxima appeared of about the same brightness, there being none of exceptional brilliancy, as had been observed during previous years.

4. *U Monocerotis.* 2676

This star was observed on 57 evenings, extending from 1887 November 21 to 1888 May 7. From these, 6 good determinations of maxima and minima have been fixed, as follows:

Maximum =	1887 Dec. 15.0	Light =	25.3
	1888 Jan. 31.0		26.8
	Mar. 13.0		22.4
Minimum =	1888 Jan. 13.0	Light =	5.4
	Feb. 27.5		19.8
	Apr. 11.0		12.5

The second minimum was a remarkably bright one. The interval between the first and second maximum was 47 days; and between the second and third, it was 45 days. The interval between the first and second minima was 42.5 days; and between the second and third, 43.5 days.

5. *R Virginis.* 4521

This star was observed from March 15 to May 8; the observations numbering 10. When first seen, on March 15, *R* was = DM. 8°,2626, and 3 steps < DM. 8°,2634, or 8^{m}.4. The increase of light was rapid and uniform; a maximum being passed on April 8. Maximum brightness 3 or 4 steps > DM. 8°,2617, and 2 steps < DM. 8°,2619, or 7^{m}.0. The star very rapidly declined; and when last seen, on May 8, was 5 steps > DM. 7°,2558, and 5 steps < DM. 8°,2626, or 8^{m}.8.

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6. *T Ceti.* 110

The observations of this star number 12, and extend from 1888 September 5 to 1889 January 29. When first observed, on September 5, *T* was very bright, and = 18 (*U.A.*) *Ceti*, or $5^{M}.4$. The decrease of light after September 5 appeared slow and regular, and a rather faint minimum was passed December 3. Minimum brightness 4 or 5 steps < 28 (*U.A*) *Ceti*, and 1 step > 21 (*U.A.*) *Ceti*, or $6^{M}.9$. *T* remained faint for only a few days, when it rapidly brightened, and on January 25 it was again very bright, being 2 or 3 steps > 18 (*U.A.*) *Ceti*, and 5 steps < 15 (*U.A.*) *Ceti*, or $5^{M}.0$, and so remained until January 29, when the observations terminated owing to the star's near approach to the sunset horizon.

7. *R Coronae Borealis.* 562

This was observed from March 6 to November 3, 47 observations being obtained. On March 6, the date of the first observation, *R* was 2 steps > DM. 30°,2682, and 5 + steps < DM. 32°,2621, or $6^{M}.5$. Its brightness remained apparently constant until June 1, when an increase of 2 or 3 steps occurred, and a standstill until August 24, followed by another slight increase of 1 or 2 steps, with no further changes up to November 3, the date of the last observation. When brightest, *R* was 5 + steps > DM. 30°,2682, and 3 steps < DM. 32°,2621, or about $6^{M}.1$.

8. *ρ Persei.* 1072

This star was observed on 9 evenings, from 1888 September 26 to 1889 January 29. Although serious gaps occur at critical points of the light-curve, a minimum is indicated as occurring about November 7.

9. *U Orionis.* 2110

This star has recently passed another bright maximum. The observations number 25, and extend from 1888 November 30 to 1889 February 8. When first seen, on November 30, *U* was found to be quite bright, being 2 steps > DM. 19°,1106, and 3 or 4 steps < DM. 20°,1156, or $7^{M}.0$. The increase was rapid, and a maximum was passed on December 26; the maximum brightness being 2 or 3 steps > DM. 19°,1110, and 4 steps < DM. 19°,1126, or $6^{M}.2$. The brightness remained nearly constant from December 20 to January 3. The decrease appeared very slow at first, but afterwards quite rapid. The star is now (February 8) 3 steps > DM. 19°,1106, and 2 steps < DM. 20°,1156, or $7^{M}.0$.

10. *U Ceti.*

Observed from 1888 September 27 to 1889 January 3. When first seen, on September 27, *U* was 5 steps > SDM. 13°,483, and 5 steps < SDM. 13°,492, or about $8^{M}.1$. The increase of light was rapid, and a maximum was passed on October 22, the maximum brightness being 4 steps > SDM. 13°,495, and 3 steps < SDM. 13°,457, or $7^{M}.0$. The decrease was very slow and regular, and when last seen, on January 3, *U* was 3 steps < SDM. 13°,481, or about $8^{M}.8$. The interval between the last 2 maxima was 241 days.

11. *o Ceti.* 706

The observations on this star number 35, and extend from 1887 September 10 to 1888 March 3. When first seen *o* was 5 steps < 242 (*U.A.*) *Ceti*, or about $7^{M}.5$. The increase of brightness was rapid and quite uniform; and a maximum was passed 1887 November 10, the brightness being then 4 steps > 270 (*U.A.*) *Ceti*, and 4 steps < 308 (*U.A.*) *Ceti*, or $4^{M}.9$. When last observed, on March 3, *o* was = SDM. 4°,379, or about $8^{M}.5$.

12. *R Sculptoris.* 484

A few observations were obtained of this difficult star, extending from 1888 December 20 to 1889 January 29. *R* was estimated about $7^{M}.6$, when first seen (comparison-stars not yet identified) evidently near minimum. It was slightly brighter on January 1, and had further increased in brightness 2 or 3 steps on January 29, the date of the last observation. *R* had certainly passed a minimum.

13. *R Corvi.*

This star was occasionally observed from May 7 to June 29 (5 observations). When first seen, on May 7, *R* was = SDM. 18°,3368, and 2 or 3 steps < SDM. 18°,3369, or about $8^{M}.2$. The increase appeared rapid, and a maximum was passed about June 5, the maximum brightness being = SDM. 19°,3445, and 5 steps > SDM. 18°,3379, or $6^{M}.9$. The decrease was not well observed, owing to the close approach of the star to the sun; but when last seen it was 3 steps < SDM. 19°,3445, and 2 steps > SDM. 18°,3379, or about $7^{M}.2$.

14. *W Cygni.* 7754

The observations of this star number 48, and extend from 1888 June 1 to 1889 February 19. When first seen, on June 1, *W* was 4 or 5 steps > DM. 44°,3889, and 2 steps < DM. 46°,3305, or $6^{M}.3$. The light remained constant until June 18. *W* had evidently just passed a bright maximum, probably about June 5(?). The light declined quite rapidly after June 18, and from August 1 to September 26, a period of 57 days, remained apparently constant. A faint minimum was passed August 24, the brightness being 3 steps > DM. 45°,3584, 2 steps < DM. 43°,4002, and 5 + steps < DM. 44°,3889, or $6^{M}.8$. From September 26 to October 24, the star brightened very slowly, and then very rapidly until November 2; a rather faint maximum being reached about November 12 (a bad gap here occurs in the series, extending from November 7 to 30), the brightness being 5 steps > DM. 43°,4002, ½ step > DM. 44°,3889, and 5 steps < DM. 46°,3305, or $6^{M}.5$. A second minimum was passed on 1889 January 1,

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the brightness being 1 step > DM. 43°,4002, and 3 or 4 steps < DM. 44°,3889, or $6^{M}.8$. The star is now (February 19) brightening very fast. The interval between the 2 minima was 130 days.

Brighton, Mass., 1889 *February*.

15. *ε Aurigae.* 1768

Occasionally observed from 1888 November 30 to 1889 February 24. A minimum phase is indicated about 1889 January 15.

OCCULTATION OF JUPITER, 1889 MARCH 23,

By WILLIAM BELLAMY.

The accompanying tables give, for places at intervals of 4° in longitude, and 2° in latitude, the times from Greenwich mean noon, March 23, of the immersion and emersion of *Jupiter's* center. They ought not to be in error more than ±1 minute. The first contact of the disks precedes about 1 minute, and the first occultation of a satellite (the 3d) precedes about 10 minutes, the time of occultation of the center.

Immersion.

Lat. N.	Longitude West from Greenwich.													
	124°	120°	116°	112°	108°	104°	100°	96°	92°	88°	84°	80°	76°	72°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
46	22 28	22 32	22 36	22 42	22 48	22 55	23 2	23 10	23 19	23 28	23 37	23 45	23 52	23 58
44	25	29	33	38	44	51	22 58	6	13	24	33	42	49	56
42	22	26	30	35	41	48	55	2	10	20	30	39	47	54
40	20	23	27	32	37	44	52	0	9	18	27	36	44	
38	18	21	24	29	34	41	49	22 58	7	16	24	33	42	
36		19	22	27	32	38	46	55	3	13	22	31	40	
34		17	20	25	30	36	43	51	22 59	9	20	29	39	
32							41	49	57	7	18	29	41	
30							39	47	56	5	16	28	44	

Emersion.

Lat. N.	Longitude West from Greenwich.													
	124°	120°	116°	112°	108°	104°	100°	96°	92°	88°	84°	80°	76°	72°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
46	23 31	23 33	23 36	23 40	23 44	23 48	23 53	23 58	24 3	24 9	24 16	24 23	24 31	24 39
44	29	32	36	40	44	49	54	59	5	12	19	27	35	44
42	28	30	35	40	45	50	55	24 1	8	15	23	31	40	48
40	26	30	35	39	45	50	57	3	10	18	26	34	43	
38	25	29	34	39	45	51	58	5	12	20	29	38	47	
36		28	33	39	45	51	59	6	14	23	32	40	50	
34		27	33	38	44	52	24 0	8	16	25	34	44	54	
32							0	9	18	27	37	46	56	
30							1	10	19	29	39	49	59	

Angle from North Point at Emersion.

Lat. N.	Longitude West from Greenwich.													
	124°	120°	116°	112°	108°	104°	100°	96°	92°	88°	84°	80°	76°	72°
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
46	302	306	310	314	318	322	326	329	332	335	338	335	332	328
44	298	302	306	310	314	317	321	324	326	328	330	328	326	323
42	294	298	302	306	309	313	317	319	321	322	323	322	320	318
40	289	294	297	302	306	309	312	315	317	318	319	317	316	
38	284	289	293	298	302	305	308	311	313	314	315	313	311	
36			289	293	297	300	303	306	308	309	309	308	306	
34			284	288	292	295	299	301	303	304	304	303	301	
32							295	297	299	300	299	298	296	
30							290	292	294	295	294	293	291	

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OBSERVATIONS OF COMETS,

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

[Communicated by the Superintendent.]

1889 Wash. M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
				Comet *e* (Barnard).					
d h m s			m s	′ ″	h m s	° ′ ″			
Jan. 18 7 6 11.7	1	15 , 3	+0 32.94	— 3 20.5	23 54 50.12	— 6 10 15.3	9.525	0.778	F
21 7 13 29.5	2	25 , 5	+0 52.47	+ 7 46.3	23 52 18.16	— 5 56 48.1	9.566	0.773	F
29 6 52 25.4	3	20 , 4	—1 47.20	+ 0 19.8	23 47 4.39	— 5 20 18.9	9.587	0.767	F
30 7 13 15.6	3	10 , 2	—2 19.35	+ 4 59.6	23 46 32.22	— 5 15 39.2	9.611	0.763	F
7 13 26.7	4	20 , 4	—2 52.72	+ 1 46.4	23 46 32.08	— 5 15 33.8	"	"	F
Feb. 1 6 51 55.2	5	30 , 6	+2 30.68	— 2 50.1	23 45 32.45	— 5 6 8.3	9.597	0.765	T
2 7 14 31.2	5	20 , 4	+2 2.90	+ 1 53.7	23 45 4.66	— 5 1 24.6	9.624	0.760	F
12 6 48 23.8	6	15 , 3	—1 32.31	+ 1 48.4	23 41 30.44	— 4 13 41.6	9.636	0.755	F
				Comet *f* (Barnard).					
Jan. 27 11 45 27.1	7	25 , 5	—1 27.26	+13 57.0	10 7 44.08	+17 38 35.4	n9.353	0.584	T
Feb. 2 9 28 53.8	8	20 , 4	—1 58.14	— 2 19.7	10 1 14.76	+20 50 8.9	n9.602	0.752	F
9 15 46 57.8	9	25 , 5	—2 40.29	— 3 31.1	9 52 58.81	+24 27 16.4	9.882	0.500	T
11 17 12 38.6	10	20 , 4	+1 49.78	+14 30.0	9 50 38.81	+25 24 21.4	9.688	0.616	T
18 8 3 22.7	11	15 , 3	—2 42.21	— 6 49.2	9 43 23.65	+28 10 46.8	n9.635	0.483	F
8 3 22.7	12	15 , 3	—4 13.83	— 2 9.7	9 43 23.33	+28 10 50.0	"	"	F

Mean Places for 1889.0 for Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 54 18.61	—1.43	— 6 6 44.1	—10.7	Weisse's Bessel XXIII, 1074
2	23 51 27.17	—1.48	— 6 4 23.6	—10.8	Weisse's Bessel XXIII, 1016
3	23 48 53.13	{ —1.54 / —1.56 }	— 5 20 28.0	{ —10.7 / —10.8 }	Weisse's Bessel XXIII, 960
4	23 49 26.34	—1.54	— 5 17 9.5	—10.7	Weisse's Bessel XXIII, 973
5	23 43 3.35	{ —1.58 / —1.59 }	— 5 3 7.6	{ —10.6 / —10.7 }	⅓(Weisse's Bessel+2 Yarnall)
6	23 43 4.39	—1.64	— 4 15 19.3	—10.7	Schjellerup 9844
7	10 9 10.88	+0.46	+17 24 43.5	— 5.1	Weisse's Bessel (2) X, 148
8	10 3 12.31	+0.59	+20 52 34.1	— 5.5	⅓(Weisse's Bessel+2 Yarnall)
9	9 55 38.41	+0.69	+24 30 53.0	— 5.5	Weisse's Bessel (2) IX, 1140
10	9 48 48.30	+0.73	+25 9 56.6	— 5.2	Armagh (2) 1146
11	9 46 5.07	+0.79	+28 17 40.6	— 4.6	Bonn VI+28°, 1815
12	9 47 36.37	+0.79	+28 13 5.3	— 5.6	Yarnall 4122

The observers are Frisby and Tuttle.

CONTRIBUTIONS TO THE KNOWLEDGE OF THE INEQUALITIES IN THE PERIODS OF THE VARIABLE STARS,

By S. C. CHANDLER.

II.

5501. *S Serpentis.*

The numerical representation of the irregularities of this star has long been a matter of difficulty. Argelander's investigation (*A.N.* 48, 379), represented the observations from 1828 to 1858 (and also Lalande's magnitude estimate of 1794 May 17, when the star must have been near maximum), by a shortening of the period from epoch to epoch of about three-eighths of a day. Later (BB. VII, 384), he recognized the incorrectness of this idea, and the necessity of awaiting further data. For the purpose of his catalogue, Schönfeld contented himself with a uniform period of 361 days, avowedly disregarding both Lalande's and Harding's observations. The maxima observed since 1874 by Schmidt and myself, seem to demonstrate that the change in period has reversed the sign which prevailed before 1858. According to the interpretation which the elements of my catalogue

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place upon the observations, the period was not shortening between LALANDE and HARDING, as ARGELANDER supposed, but was, on the contrary, rapidly lengthening, and attained its maximum value, about 370 days, near HARDING's time; then diminished to about 360 days near 1858; and has since again become longer, being now once more near its maximum. The variations O—C in the table are from the elements,

$$1828 \text{ April } 19.0 + 364.8E + 50 \sin(6°E+5°),$$

which must serve until current observations supply means for further adjusting the constants.

Calculated Maxima

Epoch	61	1889 April 1
	62	1890 April 6
	63	1891 April 11

E	Obs'd Max.	O—C	Obs.	E	Obs'd Max.	O—C	Obs.
—34	94 May 17	—3.1	Ll	+29	57 Apr. 15	+8.0	A
0	28 Apr. 28	+4.7	Hd	30	58 Apr. 8	+6.3	"
+ 2	30 May 7	+3.8	"	31	59 Mar. 30	—2.3	"
4	32 May 9	—2.4	"	"	Mar. 25	+2.7	Wn
15	43 May 30	—1.8	A	37	65 Feb. 26	+1.0	Sd
16	44 May 22	—8.9	"	38	66 Feb. 26	+4.6	"
17	45 May 29	—0.4	"	39	67 Feb. 25.5	+7.1	"
18	46 May 31	+3.6	"	"	Feb. 15:	—3.4:	A
19	47 May 28	+3.0	"	40	68 Feb. 23	—2.7	Sd
20	48 May 19	—1.9	"	41	69 Feb. 12	—0.5	"
24	52 May 3	—0.9	"	42	70 Feb. 12	+1.1	"
25	53 May 4	+4.9	"	44	72 Feb. 2	—6.0	"
26	54 Apr. 26	+1.9	"	46	74 Feb. 6	—2.1	"
27	55 Apr. 20	+1.2	"	51	79 Feb. 14.2	—3.8	Sm
+28	56 Apr. 12	—0.5	"	+56	84 Mar. 12:	+3.5	Ch

5677. *R Serpentis.*

As in the case of the preceding star, ARGELANDER found distinct evidence of shortening of the period between HARDING's time and 1868, amounting to about a quarter of a day from epoch to epoch. But he recognized that his formula placed the maximum of 1783 much too early for D'AGELET's observations, and that the attempt to ascertain the correct formula was then premature (BB. VII, 385). SCHÖNFELD found that all the observations could be moderately well satisfied by the expression,

$$1853 \text{ Oct. } 21.0 + 356.34E - 0.01E^2 + 30 \sin(9°+144°),$$

which, however, gives the maxima since 1875 too late, the difference amounting to more than a month by my observed maximum of 1884, which is the latest recorded. I have somewhat modified the constants of my catalogue, which now read,

$$1827 \text{ May } 7.0 + 357.6E + 48.0 \sin(\tfrac{60}{11}°E+8°),$$

in deducing which I have disregarded SCHMIDT's rather vague indication of the maxima of 1881 and 1882. The deviations from this formula are given in the column O—C.

Calculated Maxima.

Epoch	63	1889 Jan. 3
	64	Dec. 31
	65	1890 Dec. 28
	66	1891 Dec. 25

Observations of both maxima and minima of this, as well as of the preceding star, are very much needed.

E	Obs'd Max.	O—C	Obs.	E	Obs'd Max.	O—C	Obs.
—45	83 Apr. 28	—27.5	d'A	+40	66 May 25	— 6.3	Sd
0	27 May 14	+ 0.3	Hd	41	67 May 17	— 4.0	"
+16	43 Feb. 17	— 4.4	A	42	68 May 10.5	+ 0.6	"
17	44 Feb. 13	— 0.3	"	43	69 Apr. 27	— 3.2	"
26	52 Nov. 16	+ 3.3	"	44	70 May 2	+11.1	"
27	53 Nov. 1	— 0.3	"	45	71 Apr. 20	+ 8.0	"
29	55 Oct. 19	+10.1	"	46	72 Apr. 10	+ 7.5	"
30	56 Oct. 4	+ 8.0	"	47	73 Mar. 31	+ 5.6	"
"	Oct. 4.5	+ 8.5	Sd	48	74 Mar. 24	+ 6.2	Sm
31	57 Sept. 15	+ 0.9	A	"	Mar. 27	+ 9.2	Sd
"	Sept. 16.0	+ 1.9	Sd	49	75 Mar. 10	— 0.6	"
32	58 Aug. 26	— 7.1	A	50	76 Feb. 29.2	— 2.7	Sm
"	Aug. 24	— 9.1	Sd	51	77 Mar. 5	+ 8.5	Sb
"	Aug. 31	— 2.1	Au	52	78 Feb. 20	+ 1.4	"
33	59 Aug. 23	+ 1.9	A	55	81 Mar. 4	—(+29.8)	Sm
"	Aug. 24	+ 2.9	Au	56	82 Feb. 26	—(+28.3)	"
"	Aug. 25	+ 4.1	Wn	+58	84 Jan. 10	—10.5	Ch
+39	65 June 5	— 6.1	Sd				

5770. *R Herculis.*

I place a somewhat different construction upon the observations from what SCHÖNFELD has done, in his catalogue of 1875. A notably rapid lengthening, indeed, took place in the period from discovery up to 1865; but its value was then about 322 days, apparently near its maximum, and thereafter diminished for the rest of that decade and during the whole of the next. The most plausible assumption, to account for the observed variations, is an inequality of unusually short duration, which I take, tentatively, to be 30 periods of the star. The deviations in the table below are from the elements of my catalogue, which involve this assumption. They are,

$$\text{Max. } 1865 \text{ July } 18.0 + 318.4E + 20 \sin(12°E+324°).$$

Doubtless some improvement might be made in the constants adopted, but the attempt seems to be scarcely warranted until further observations, which are much needed, have been secured.

Calculated Maxima

Ep.	27	1889 Jan. 11
	28	Nov. 27
	29	1890 Oct. 13
	30	1891 Aug. 31

E	Obs'd Max.	O—C	Obs.	E	Obs'd Max.	O—C	Obs.
—46	25 June 13	—13.4	Bl	+ 3	68 Mar. 13	+13.8	Sd
10	56 Nov. 3	+13.1	Sd	6	70 Oct. 23	+ 0.8	"
7	59 May 28.5	+ 3.6	"	7	71 Sept. 1	— 7.7	"
"	May 30.5	+ 5.5	Au	8	72 July 26	+ 0.5	"
"	June 3	+ 9.1	Wn	10	74 Apr. 28	+ 2.1	"
— 6	60 Apr. 28	— 8.6	Au	11	75 Mar. 7	— 3.3	"
0	65 July 6	— 0.2	Sd	16	79 June 24.5	—13.0	Sm
+ 1	66 May 29	+ 4.7	"	17	80 May 15.5	— 1.5	"
+ 2	67 Apr. 14	+ 2.4	"	+21	83 Oct. 25	— 1.6	Ch

6044. *S Herculis.*

SCHÖNFELD's period of 303 days prevails only from 1856 to 1872. Even in this interval the departures are systematic, and far larger than the errors of observation; and he points out that his elements also fail to accord with the visibility of the star in the Greenwich meridian instruments on 1840 July 9, and 1846 July 3, dates, by the way, which he has re-

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versed by a slip of the pen. From about 1870 to the present time the period has increased at a most extraordinary rate, the more recent maxima requiring a value of about 313 days. An inspection of the results makes it evident that a highly developed law is here involved. In the catalogue I gave the first sine-term in the elements below, but stated that the result was provisional, because, while it conformed to the general character of the observed departures from uniform period, the outstanding differences were systematic and much greater than the observation-errors. An additional sine-term reduces these, but it is manifestly too early to get good values of the various coefficients. In the table of observed maxima and minima I make a comparison with the elements,

$$\left.\begin{array}{l}\text{Max. 1856 Aug. 30.0}\\ \text{Min. 1856 Mar. 27.0}\end{array}\right\} +309.2E+55.0\sin(\ 7^\circ.5E+100^\circ) \\ +18.0\sin(15^\circ.0E+\ 61^\circ)$$

From a comparison of the values of the first periodical term in the fourth column with O—C′, and of the second term in the sixth column with O—C″, they do not seem to be entirely illusory; although the final column, O—C, leaves chance for improvement. Further refinement of results at the present time, however, would be waste of labor.

The elements give for Ep. —87, Max. 1783 Jan. 12, and for Ep. —74, 1794 Nov. 22, thus harmonizing with the fact that D'Agelet on 1783 Apr. 27, and Lalande on 1794 June 13, overlooked the star; they give further, for Ep. —38, 1824 June 25, and are therefore consistent with Rosenberger's observation in the meridian circle at Königsberg, 1824 Apr. 21–23, when no magnitude was assigned.

Winnecke's maximum of 1859 is omitted in the table, as he has given conflicting dates, and it is, besides, well determined by Schönfeld and Auwers.

The following phases are calculated, using only the first periodical term in the above elements.

Epoch	Maxima	Minima
39	1889 Oct. 4	1889 May 1
40	Aug. 15	1890 Mar 12
41	1891 June 25	1891 Jan. 20
42	1892 May 4	Nov. 30

E	Obs'd Max.	O—C′	1st Term	O—C″	2d Term	O—C	Observer
—19	40 July 9	—21.2	—37.1	+15.9	+12.5	+ 3.4	Greenwich
—12	46 July 3	— 0.6	+ 9.6	—10.2	—15.8	+ 5.6	"
0	56 Nov. 7.5	+69.5	+54.2	+15.3	+15.8	— 0.5	Schönfeld
+ 3	59 May 6	+51.4	+46.4	+ 5.0	+17.3	—12.3	"
"	May 8.5	+53.9	+46.4	+ 7.5	+17.3	— 9.8	Auwers
10	65 Feb. 23	+ 7.0	+ 4.8	+ 2.2	— 9.2	+11.4	Schönfeld
12	66 Oct. 11	—16.4	— 9.6	— 6.8	—15.8	+ 9.0	"
13	67 Aug. 5	—27.6	—16.5	—11.1	—17.5	+ 6.4	"
14	68 May 18	—49.8	—23.3	—26.5	—18.0	— 8.5	"
18	71 Sept. 30	—56.6	—45.0	—11.6	— 8.7	— 2.9	"
19	72 July 25	—66.8	—48.8	—18.0	— 4.3	—13.7	"
21	74 Apr. 28	—43.2	—53.7	+10.5	+ 5.0	+ 5.5	"
24	76 Nov. 25	—28.8	—54.2	+25.4	+15.7	+ 9.7	Schmidt
27	79 June 4.9	—34.5	—46.4	+11.9	+17.3	— 5.4	"
28	80 Apr. 15.5	—28.1	—42.1	+14.0	+15.3	— 1.3	"
31	82 Oct. 31	—27.2	—25.3	— 1.9	+ 4.3	— 6.2	"
32	83 Sept. 12.8	—19.6	—18.8	— 0.8	— 0.3	— 0.5	
"	Sept. 12	—20.4	—18.8	— 1.6	— 0.3	— 1.3	Chandler
33	84 July 24	—13.6	—11.9	— 1.7	— 5.0	+ 3.3	Baxendell
+34	85 June 11	— 0.8	— 4.8	+ 4.0	— 9.3	+13.3	"
	Minima						
+11	65 July 11	—18.2	— 2.4	—15.8	—13.0	— 2.8	Schönfeld
12	66 May 11	—13.4	— 9.6	— 3.8	—15.7	+11.9	"
16	69 Aug. 27	—46.2	—34.3	—11.9	—15.4	+ 3.5	"
17	70 June 30	—58.4	—40.6	—17.8	—12.5	— 5.3	"
18	71 Apr. 25	—58.6	—45.0	—13.6	— 8.7	— 4.9	"
21	73 Nov. 12	—54.2	—53.7	— 0.5	+ 6.1	— 6.6	"
+22	74 Sept. 28	—43.4	—54.8	+11.4	+11.3	+ 0.1	"

6512. *T Herculis*.

For the discussion of the elements of this star I have collected 35 observed maxima and 28 minima, extending from 1856 to 1886, inclusive. Instead of giving the separate observations, however, the data are here presented much in the same form as has already adopted for *R Virginis*. The following normal epochs were based upon three or four determinations each, as specified in the first column. Subsequent discussion of them resulted in the following elements:

$$\left.\begin{array}{l}\text{Max. 1868 Mar. 9.3}\\ \text{Min. 1867 Dec. 22.3}\end{array}\right\} +164.75E+6.5\sin(7^\circ.5E+52^\circ.5)$$

where the epochs and period are the same as in the catalogue, but the goniometric constants have been slightly improved.

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Table of Normal Epochs.

No.	E	Normal Epoch	O—C′	Sine Term	O—C
		MAXIMA.			
3	—22	1858 Apr. 4.0	— 2.8	—6.0	+3.2
3	— 5	1865 Dec. 5.7	— 0.8	+1.7	—2.5
3	— 2	1867 Apr. 19.1	+ 4.3	+4.0	+0.3
4	+ 4	1870 Jan. 7.7	+10.4	+6.4	+4.0
4	9	1872 Apr. 3.3	+ 3.3	+5.7	—2.4
3	14	1874 July 5.5	+ 2.7	+2.5	+0.2
3	26	1879 Nov. 28.6	— 2.2	—6.0	+3.8
3	30	1881 Sept. 10.7	— 9.1	—6.4	—2.7
4	35	1883 Dec. 16.5	— 6.0	—4.6	—1.4
5	38	1885 Apr. 26.2	— 3.6	—2.5	—1.1
		MINIMA.			
4	—20	1858 Dec. 5.7	— 8.6	—6.5	—2.1
3	— 5	1865 Sept. 23.7	+ 4.1	+1.7	+2.4
3	— 1	1867 July 12.7	+ 2.2	+4.6	—2.4
4	+ 4	1869 Oct. 19.2	+ 7.9	+6.4	+1.5
4	9	1872 Jan. 20.7	+ 7.7	+5.7	+2.0
4	14	1874 Apr. 18.9	+ 3.1	+2.5	+0.6
3	30	1881 June 24.8	— 9.0	—6.4	—2.6
3	39	1885 July 22.8	— 2.8	—1.6	—1.2

The column O—C′ gives the comparison with the first two terms of the elements, *i.e.*, the deviations from uniform periodicity; the periodic term follows in the fifth column; and finally the outstanding residuals in the last column. The sine-term reduces the sum of squares of residuals from 289.9 to 63.3 for the maxima, and from 315.8 to 30.7 for the minima, and its reality is, I think, beyond doubt.

The elements give the minimum epoch —152, as 1799 June 5, and therefore account satisfactorily for Lalande's failure to record the star in his zone, 1799 June 22.

E	Calculated Maxima	Calculated Minima
48	1889 May 27	1889 Mar. 10
49	Nov. 8	Aug. 22
50	1890 Apr. 22	1890 Feb. 3
51	Oct. 4	July 18
52	1891 Mar. 18	Dec. 30
53	Aug. 30	1891 June 13

THE OUTER RING OF *SATURN*,

By JAMES E. KEELER, Astronomer of the Lick Observatory.

In the *Sidereal Messenger* for February, 1888, and more recently in *Ciel et Terre*, I described the appearance of a very fine division on the outer ring of *Saturn*, which was seen on several occasions with the 36-inch equatorial immediately after its erection at the observatory, and particularly well on the night of 1888 January 7. In the year which has elapsed since the time of its discovery, the division has been repeatedly looked for by different members of the observatory staff, but without success; and I had come to the conclusion that it was either invisible by reason of the greater obliquity of the ring, or that it was of temporary character, and no longer existed. More recent observations show that our failure was due simply to the lack of sufficiently good definition.

On the night of March 2, which was one of the finest that we have had at the observatory, the division was seen by Professor Holden, Mr. Schaeberle, Mr. Barnard and myself, and was independently estimated by all four observers to be situated at one-sixth of the width of the outer ring from its outer edge.

Mr. Barnard and I continued to observe the planet, with different magnifying powers, until after it had passed the meridian. The brilliancy of the whole system, particularly of the gauze ring, was remarkable, and the outlines appeared with a sharpness more characteristic of the lines of a steel engraving than of the usual telescopic image. With a power of 400, a faint shading could be seen on the outer ring *A*, at about one-third of its width from the outer edge. If no higher power had been available, we should have said that we had had an excellent view of the Encke division (or shading).

With a power of 1500 the appearance was different. The division near the outer edge of the ring then became visible, not as a shade, but as a distinct black line of exceeding fineness, and from this a dark shading extended inward nearly to the inner edge of the ring. Mr. Barnard placed the maximum depth of shade at one-third the distance from the outer edge, or where the Encke shading appeared with the lower power. To one it seemed farther out, nearly at the division which separated the shading from the brighter margin of the ring. The narrow strip lying between the division and the outermost edge of the system appeared to both of us to be the brightest part of ring *A*.

The outline of the planet's shadow on the ring was seen with the greatest distinctness, and was a perfectly smooth curve, agreeing, as nearly as we could judge, with that required by geometrical principles. A very minute irregularity could easily have been detected.

In my opinion the division described above is a permanent feature of the outer ring, but it is so minute that it may fairly be classed among the most difficult and delicate of planetary details, requiring the most powerful instruments and exceptional atmospheric conditions for its observation.

Lick Observatory, Mt. Hamilton, 1889 *March* 4.

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SOME OBSERVATIONS OF THE VARIABLE STAR *U GEMINORUM*,

2815

BY PAUL S. YENDELL.

During January and February of the current year I have obtained seven observations of this star.

A watch was begun for it 1888 December 24, and it was looked for on every available opportunity, but not seen until 1889 January 3, when it was found in the field, where it had certainly not been visible on the evening of January 1, when it was looked for. At this observation the star's light was estimated as a rather bright 9th magnitude, being 4 steps > DM. +22° 1815; it was easily identified by its light and its livid bluish color.

Unfavorable weather prevented further observation until January 11, when the star was again looked for, but not seen.

On the 23d of January, as I was observing in its neighborhood, I turned the telescope on *U*, and was considerably surprised to find the star again visible; the fact of its having been seen three weeks before threw a doubt on the identity of the object, but a careful alignment and comparison with the chart, together with the star's subsequent behavior, placed the matter beyond a doubt.

The star's light at this observation was estimated to be = DM. +22° 1811, or $9^{M}.3$; the observations obtained were as follows:

1889 Jan.	23.33	$9^{M}.3$
	25.3	9.3
	29.33	9.6
	30.29	9.8
	31.32	10.3
Feb.	1.31	11.0

From the first two observations it appears probable that the star may have passed a maximum January 24, but the absence of any observations which may with certainty be assigned to the rising curve, leaves the question in doubt.

The instrument used was my Clacey 4½-inch refractor, with one eyepiece, giving a power of 36, and a field of about 80′.

Dorchester, Mass., 1889 *March* 6.

COMETS OF THE YEAR 1888.

The Dates are in Greenwich Mean Time, and the Elements only approximate.

Designation	Perihelion	☊	ω	i	q	φ	Discoverer	Date	Synonym	
		° ′	° ′	° ′		° ′				
I	Mar. 16.999	245 23	359 55	42 15	0.6988	84 16	Sawerthal	Feb. 18	*a* 1888	elliptic
II	June 27.990	334 39	183 57	12 53	0.3431	57 43	Tebbutt	July 8	*b* 1888	Encke's
III	July 31.155	101 30	59 14	74 12	0.9023		Brooks	Aug. 7	*c* 1888	
IV	Aug. 19.537	209 42	201 14	11 20	1.7381	33 18	at Nice	Aug. 9	*d* 1888	Faye's
V	Sept. 12.998	137 35	291 4	56 27	1.5216		Barnard	Oct. 30	*f* 1888	elliptic?

The comet *e* 1888, discovered by BARNARD Sept. 2, is probably 1889 I.

REPORTED CHANGE IN *SATURN'S* RING.

A telegram from Kiel, March 13, says:

TERBY announces "*region blanche sur anneau Saturne contre ombre globe.*"

This we translate as giving notice of the appearance of a white region upon the ring, adjacent to the shadow of the planet itself.

Professor C. H. MACLEOD of Montreal telegraphs, "Bright spot in ring observed; appears brightest toward inner edge."

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THE

ASTRONOMICAL JOURNAL.

No. 191.

VOL. VIII. BOSTON, 1889 APRIL 15. NO. 23.

ON THE ELEMENTS AND LIGHT-VARIATION OF *X CYGNI*,

BY PAUL S. YENDELL.

The variability of this star was discovered by Mr. CHANDLER in 1886, and announced by him in the *Astronomical Journal*, Vol. VII, p. 32. This announcement was followed by the publication, on p. 59 of the same volume, of his observed times of maximum and minimum, together with his elements deduced therefrom; which elements were afterward adopted in his Catalogue of Variable Stars, in which the star is No. 7437.

I began observing this star in May, 1888; a rough experimental reduction of the first six or eight weeks' observations rather indicated that the period assigned might be in error, but no further reduction was made until toward the beginning of December, 1888. Upon reducing and plotting all the observations, it became evident that no hypothesis, based on the above-mentioned elements, would satisfy the observed discrepancies; my observations were continued until the beginning of the current month, when a consideration of my results, and comparison with Mr. CHANDLER's published times of maximum, showed an entire revision of the star's elements to be necessary. The observations of Mr. SAWYER, made in the summer and winter of 1887, and kindly communicated by him in a graphic form, were of important assistance in arriving at this conclusion. These are not given here, as Mr. SAWYER contemplates publishing them hereafter.

To arrive at the new elements, an experimental period, being the mean one indicated by my own observations, was employed, with the principal epoch given by Mr. CHANDLER; from this, hypothetical elements were deduced by a graphic process, the residuals from which, treated by the method of least squares, give the following elements, which appear to be the best at present attainable.

$$1886 \text{ Oct. } 10^{d}\, 6^{h}\, 11^{m}.8 \text{ C.M.T.} \pm 52^{m}.3. + 16^{d}\, 9^{h}\, 36^{m}\, 51^{s} \pm 2^{s}.3\, E$$

The probable error of a single determination of maximum, of weight unity, is $\pm 0^{d}.69$.

The residuals obtained by the use of these elements group themselves in a manner to slightly suggest a periodical irregularity in the time of variation, but further observations are needed to decide whether this is real or merely subjective.

In arriving at these results, the maxima alone were employed, as the variation of the interval between the minimum and maximum, which is from $3^{d}.3$ to $8^{d}.7$, with the flatness of the light-curve at minimum make the maximum phase the only one which it is possible to fix with precision; the same characteristics, together with the great fluctuation in the star's light-range, render any mean light-curve that could be drawn of little or no value in reducing the observations; on this account my times of maxima and minima given in the subjoined table were, without exception, obtained by POGSON's method from the single light-curves.

In the table the epochs from Mr. CHANDLER's elements and my own, above given, are respectively designated by *EC* and *EY*; the residuals are in like manner distinguished by the same initials.

OBSERVED MINIMA.

EC	*EY*	Cambridge M.T.	*C* O—C	*Y* O—C	*p*	Observer
		d				
3	3	1886 Nov. 25.0	+2.3	+3.5	½	Chandler
4	4	Dec. 8.6	+0.5	+0.7	1	"
5	5	Dec. 25.0	—1.3	+0.7	1	"
6	6	1887 Jan. 11.3	+0.8	+1.6	1	"
24	23	Oct. 15.3	—0.3	—0.2	1	"
25	24	Oct. 31.1	—1.7	—0.8	1	"
26	25	Nov. 16.9	—0.5	—0.4	1	"
27	26	Dec. 4.3	+1.3	+0.6	1	"
39	37	1888 June 2.4	—4.8	+1.2	½	Yendell
40	38	June 18.2	—4.6	+0.6	1	"
41	39	July 3.8	—4.6	—0.2	1	"
42	40	July 20.8	—3.2	+0.4	1	"
44	42	Aug. 23.8	—0.4	+1.6	1	"
45	43	Sept. 7.3	—1.5	—0.3	1	"
46	44	Sept. 24.4	0.0	+0.4	½	"
47	45	Oct. 10.6	+0.6	+0.2	1	"
48	46	Oct. 27.8	+2.2	+1.0	1	"
49	47	Nov. 11.3	+1.3	—0.9	1	"
50	48	Nov. 28.4	+2.6	—0.2	1	"
51	49	Dec. 14.6	+3.2	—0.4	1	"
52	50	Dec. 29.1	+2.1	—1.3	1	"
53	51	1889 Jan. 15.6	+4.0	—1.2	1	"
54	52	Feb. 1.2	+5.0	—1.0	1	"
55	53	Feb. 17.2	+5.4	—1.4	1	"

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Observed Maxima.

EC	*EY*	Cambridge M.T.	*C* O—C	*Y* O—C	*p*	Observer
3	3	1886 Nov. 28.3 d	—0.9	—0.2	1	Chandler
4	4	Dec. 13.7	—1.1	—1.2	1	"
5	5	Dec. 31.9	+1.5	+0.6	1	"
6	6	1887 Jan. 16.1	+1.1	—0.6	½	"
22	21	Sept. 21.2	—0.4	+1.5	½	"
23	22	Oct. 7.4	+0.2	+1.3	1	"
24	23	Oct. 22.7	—0.1	+0.2	1	"
25	24	Nov. 8.3	+0.9	+0.4	1	"
26	25	Nov. 23.7	+0.7	—0.6	1	"
39	37	1888 June 8.3	—4.5	+0.8	1	Yendell
40	38	June 26.6	—1.8	+1.6	1	"
41	39	July 11.7	—2.4	+0.8	1	"
42	40	July 28.8	—0.8	+1.5	1	"
44	42	Aug. 30.2	+0.4	+1.1	1	"
45	43	Sept. 14.1	—0.3	—0.4	½	"
46	44	Sept. 29.6	—0.4	—1.3	1	"
47	45	Oct. 17.3	+1.7	0.0	1	"
48	46	Nov. 4.0	+3.8	+1.3	1	"
49	47	Nov. 18.3	+2.5	—0.8	1	"
50	48	Dec. 6.0	+4.6	—0.5	1	"
51	49	Dec. 21.6	+4.6	—0.3	1	"
52	50	1889 Jan. 6.8	+5.2	—0.5	1	"
53	51	Jan. 23.3	+6.1	—0.4	1	"
54	52	Feb. 8.1	+6.3	—1.1	½	"
55	53	Feb. 24.9	+7.5	—0.5	1	"

The interval from minimum to maximum is given by Mr. Chandler as 5.6 days; it fluctuates in the observations from 3.3 days to 8.7 days, as stated above; the brute mean of all the observed intervals, being 6.9 days, is used in obtaining the residuals O—C (*Y*) in the table of Minima above.

The light-fluctuations of the star are of an extremely interesting character. The halt in its decrease alluded to by Mr. Chandler on p. 32 of Vol. VII of this Journal is shown on several of the curves plotted from my own observations; especially in the case of Epoch 53, the observation made on the morning of March 2 showing a sharp rise of fully one-fourth of a magnitude since the preceding morning, and rising quite to the importance of a secondary maximum; unfavorable weather unfortunately prevented observation on the next day, and none has since been obtained of the star.

The light-curve generally rises quite sharply from minimum to maximum, the change observed at times of greatest light-range having been in several cases as much as one-half magnitude in two days; as the light-range decreases, the curve flattens, so that in the times of least variation it is as flat at the maximum as it always is at the minimum. It is noted that there is a general correspondence between the magnitudes at the two phases, so that when the star is bright at maximum, the minimum is usually bright also; and when the maximum brightness is less, the minimum is correspondingly faint. There is a strong suggestion of periodicity in this variation, which, so far as they go, Mr. Chandler's observations rather confirm than contradict; but a longer and more continuous series of observations must be had before this question can be decided.

It was at first supposed that a correspondence was indicated between this fluctuation and the variation of the interval from minimum to maximum; but this idea, while not distinctly negatived by my observations, can not be said to be definitely borne out by them, and must be left for future investigation to settle.

I subjoin a table of the observed values of the star's light at maximum and minimum phases; those of Mr. Chandler were kindly furnished by him for the purpose, in manuscript. Mr. Chandler's observations are given in his scale, as he gave them, and my own with the correction +5.5 steps, which nearly equalizes the two scales; the following are the comparison-stars used, being the same as designated by Mr. Chandler.

	α	δ	Chandler's Light-scale	Yendell's Light-scale	*Y*+5.5
a	20h 23m 48s	+35° 58′.5	15	8.5	14.0
b	20 36 43	34 56.4	10	4.5	10.0
d	20 34 16	34 52.5	7	2.7	8.2
f	20 35 9	+34 31.4	6	0	5.5

Light-Values at Maximum and Minimum.

E	Min. *C*	Min. *Y*+5.5	Max. *C*	Max. *Y*+5.5	Observer
3	4.5		12.5		Chandler
4	3.0*		13.5		"
5	4.0				"
6	4.0				"
21			13.2		"
22			11.3		"
23	6.2		12.8		"
24	6.2		12.3		"
25	3.0				"
37		7.3		11.6	Yendell
38		7.2 *		12.4	"
39		7.2		13.1	"
40		7.5 *		13.9	"
42		7.1 *		13.25	"
43		6.9		13.9 *	"
44		6.75*		12.1	"
45		6.2		12.1 *	"
46		6.2		11.1	"
47		7.2 *		13.2	"
48		5.6		11.3	"
49		6.75*		11.0	"
50		5.6		10.5 *	"
51		6.2		12.1 *	"
52		6.5		11.3 *	"
53				12.4	"

* Maxima and minima affected by moonlight.

Dorchester, Mass., 1889 *March* 11.

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A STUDY IN THE RESIDUALS OF *MERCURY*,

BY ORRAY TAFT SHERMAN.

In this Journal, No. 173, we have given a method of examining the residuals for *Mercury*, and the first results thereof. The results then given are derived from all the observations without rejection. In two cases, $v = 165°$, and $v = 255°$, a continued study was unable to find any probable forces capable of producing so large an effect. A critical examination showed it to be mainly dependent upon six large residuals occurring in one year, and at the same observatory. We may speak similarly of $v = 255°$. Rejecting these large residuals the periodic variation to LEVERRIER's second tables stands as follows:

v	δv	δr
°	″	
15	—2.64	—0.0000048
45	+1.39	—0.0000052
75	+3.04	—0.0000134
105	+0.59	—0.0000070
135	+2.54	—0.0000100
165	—0.62	+0.0000087
195	+1.64	—0.0000022
225	—0.45	—0.0000002
255	—1.92	+0.0000010
285	+0.56	—0.0000008
315	+0.70	—0.0000012
345	—4.81	—0.0000005

The increment of LEVERRIER's value of the progression of the perihelion becomes 3″.944, yielding with the constant 38″.3 an increment of 42″.244 in the century. This value agrees more closely than the former with NEWCOMB and HILL's value 42″.95. As will appear later, we may not expect a close agreement.

These values show a motion for the disturbed planet in the arc from $v = 285°$ to $v = 315°$, very nearly identical in velocity and path with the undisturbed. Starting therefrom, we have calculated, by the application of the ordinary formulae, the mean forces necessary to produce the disturbance at $v = 315°$, and also the position that should have been attained by the planet so disturbed at the time when the undisturbed planet should reach $v = 345°$. The discrepancy between the observed and thus calculated position at $v = 345°$ furnished the values of the disturbing forces for the arc $v = 315°$ to $v = 345°$. Taking the mean of these two forces, and considering it as acting uniformly through the arc $v = 285°$ to $v = 345°$, we have again calculated the position of the thus disturbed planet at the time the undisturbed planet should arrive at $v = 15°$. Thence proceeding as before.

It would have been better to represent both R and S as functions of v, integrating anew in each case, but the labor would have been thrown away in the present case.

The values of $\dfrac{R}{k^2(1+m)}$ and $\dfrac{S}{k^2(1+m)}$ obtained thereby are as follows, R being positive in the direction from the sun, and S positive in the direction of the planet's motion.

v	$\frac{R}{k^2(1+m)}$	$\frac{S}{k^2(1+m)}$
285° – 315°	—0.0000162	—0.0000035
315 – 345	—0.0001009	+0.0000056
345 – 15	+0.0000331	—0.0001191
15 – 45	+0.0001751	—0.0000053
45 – 75	+0.0007179	—0.0000853
75 – 105	+0.0008093	—0.0000961
105 – 135	+0.0002207	—0.0000052
135 – 165	+0.0000916	—0.0000003
165 – 195	—0.0001251	—0.0000351
195 – 225	—0.0001442	+0.0000006
225 – 255	—0.0007078	—0.0000021
255 – 285	—0.0017085	+0.0002764

These values gain greatly in suggestiveness when compared with their relation to the solar surface. In drawing up the following table the values for the same northern and southern latitudes have been joined as one. It will be apparent that the maximum effect is near the solar equator, and the effect decreases as the solar latitude becomes greater. The lower latitudes correspond to the sun-spot belt; the higher latitudes are in the region of least sun-spot action.

Helic. Latitude	$\frac{R}{k^2(1+m)}$	$\frac{S}{k^2(1+m)}$
0 – 18°	+0.0007622	—0.0000907
18 – 31	+0.0001979	—0.0000052
31 – 37	+0.0000623	—0.0000547
37 – 31	—0.0001180	—0.0000147
31 – 18	—0.0000804	—0.0000013
18 – 0	—0.0012082	+0.0001371

The connection thus presented with solar action should, if true, also vary in the sun-spot period. We have therefore examined, and herewith present the mean values of the variations in latitude and longitude. The grouping in the former paper has been preserved.

	Mean variation in Longitude	Mean variation in Latitude	Mean variation in Longitude	Mean variation in Latitude
	″	″	″	″
Fourth and fifth year before maximum	+1.0373	—0.4114	+0.0182	+0.1923
Second and third year before maximum	+0.2507	—0.5610	—0.3629	—0.5301
Year of maximum, year before and after	+1.5638	—0.2126	+0.0988	—0.0604
Second and third year after maximum	+0.7388	—0.1517	—0.1514	—0.1215
Fourth and fifth year after maximum	+1.8281	+0.1469	—0.0506	+0.1435

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It will be at once seen that the chief discrepancies occur in the years of increasing sun-spots. This result is strictly in accordance with the result formerly presented by the discussion of ENCKE's comet (*A. J.*, No. 181). Totally unexpected it renders a new grouping of the original observations, and a more numerous collection of observations, necessary before any numerical conclusions can be drawn.

We may note further, that the forces deflecting the planet are sunward when the planet is in that part of space towards which the sun is traveling, and away from the sun when the planet follows in his path. Taken in connection with the story told by ENCKE's comet, this would seem to indicate a considerable amount of matter coming to the sun from space. If so, its place of meeting with the matter coming from the sun should abound in collisions, and display local spectra showing bright lines. Our knowledge of the zodiacal light is fully in accord with such a supposition.

REPORTED CHANGES IN THE RINGS OF *SATURN*,

BY EDWARD S. HOLDEN, DIRECTOR OF THE LICK OBSERVATORY.

At 7 P.M., on March 13, the following telegram was received by the Lick Observatory:

> "KRUEGER cables that TERBY announces appearance of white region on *Saturn's* rings against globe's shadow.
>
> J. RITCHIE, JR."

As *Saturn* has been pretty closely followed at the Observatory during the past winter, whenever the weather would permit, it may be of interest to give our observations somewhat in detail, especially such as have been made during the month of March.

The results of examinations made previous to this time are given in a paper by myself, which is printed in the *Sidereal Messenger* for January, 1889, and in two by Mr. KEELER. The first of these was printed in *Ciel et Terre*, No. 21, p. 514 (January, 1889); the second was printed in the *Astronomical Journal*, Vol. VIII, p. 175.

On March 2, *Saturn* was carefully examined by Mr. KEELER, Mr. SCHAEBERLE, Mr. BARNARD and myself for several hours, from about 7 p.m. to midnight, under the most satisfactory conditions.

Our chief attention was directed to Ring *A*, where the new division first found by Mr. KEELER in January, 1888, was plainly seen by all of us. I looked carefully at the whole system, and I am positive that nothing abnormal was to be seen.

On March 7, a long storm began, which lasted till 2 p.m. of March 16, with heavy rain and strong gales.

On March 14, Mr. BARNARD examined *Saturn* with the 12-inch equatorial between sidereal 10^h and $10^h\ 20^m$, through rifts in the clouds. The seeing was very good; wt. = 4. Power 175. Nothing abnormal was seen.

March 15 was cloudy.

On Saturday, March 16, *Saturn* was observed by Mr. SCHAEBERLE, and Mr. KEELER, at the following hours, with the 36-inch equatorial, viz.: at 8.30, 10, 11, 12, 1, 2 P.S.T. The seeing was poor. Nothing unusual was seen by either observer, nor by myself at 8.30 and 10.

Mr BARNARD also observed with the 12-inch, powers 175 and 400, wt. 3 to 4, at sidereal times $8^h\ 50^m$, 10^h, $10^h\ 30^m$, 11^h 20, $12^h\ 5^m$. Nothing unusual was seen.

March 17 was cloudy.

On March 18, Mr. SCHAEBERLE and Mr. KEELER examined the planet with the 36-inch equatorial at $8^h\ 30^m$, $9^h\ 50^m$, 11^h, 12^h P.S.T., without seeing anything more than is described below. The seeing was poor; wt. = 1.

About $10^h\ 30^m$, I made a sketch of the appearances on the ring. The seeing was so poor that the CASSINI division was not seen to extend so far as the shadow of ball on rings. I noticed a certain deformation or lump extending across rings *A* and *B* about half as wide as the shadow, and close to it. This was ill defined, yellowish, not whitish, and I ascribed it to poor seeing. A similar appearance was seen across both *A* and *B* where they met the ball of the planet on the s. p. side. At 8 P.M., I also examined the planet with the 12-inch.

Mr. BARNARD also observed at sidereal 7^h, $7^h\ 40^m$, $9^h\ 45^m$, $11^h\ 45^m$, with the 12-inch equatorial.

March 19 was cloudy, with rain.

March 20, Mr. SCHAEBERLE and Mr. KEELER observed with the 36-inch equatorial at 8^h, 9^h, 10^h, 11^h P.S.T. I also looked carefully from $10\frac{1}{4}$ to $10\frac{3}{4}$; wt. = 2. Same appearance as March 18.

Mr. BARNARD looked at *Saturn* in the early evening with the 12-inch. Seeing nothing unusual, the rest of the night was given to photography.

On March 21, from 7.30 to 8 P.S.T., Mr. SCHAEBERLE and myself examined the planet with the 36-inch equatorial. Seeing poor; wt. = 2. Appearances as on March 18 and 20.

The lumpish appearance next the shadow (and also where the rings pass beyond the ball) was visible. It seemed to us to be due to poor vision, and to the proximity of the dark shadow to the bright ring-system. Mr. SCHAEBERLE suggested an experiment which was tried as follows:

An occulting bar was put in the eye-piece, and brought

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over different parts of the planet. Wherever it was placed a brighter confused lump seemed to rise and to border the bar. If the bar was over the ball, this brighter border extended all across the disc. If it was placed on the ring the appearance was just that of the lump bordering the true shadow of ball on rings. We therefore concluded that there was absolutely nothing abnormal on the rings, and that the appearances seen were due to bad atmospheric conditions alone. During this night the aperture of the large telescope was reduced to 12 inches for a part of the time.

Mr. BARNARD examined *Saturn* with the 12-inch at sidereal $6^h\ 50^m$, with powers 150, 175, 400, wt. = 2; and at $12^h\ 25^m$, with powers 150, 175, wt. = 3.

On March 22, the senior class of the University of the Pacific visited the Observatory between 7^h and 9^h, and our observations were not as continuous as we should have liked them to be. Shortly after the class had gone, the sky became worse. From 8^h to 9^h the seeing was superb, and a power of 2000 was used to advantage on the large equatorial. No person has ever seen *Saturn* to any better advantage, than the observers E.S.H., J.M.S. and J.E.K. The appearance of the whole planet was absolutely normal, and the fine division in Ring *A*, first seen by Mr. KEELER in January, 1888, was visible.

About 10^h the seeing became worse, wt. = 3, and the lumpish appearance on the ring near the shadow returned. It is, therefore, due to bad seeing, or at least, is only seen when the air is unsteady.

Mr. BARNARD examined the planet at sidereal 7^h and $9^h\ 30^m$ with the 12-inch.

March 24, appearances as before, with both equatorials. Observers, E.S.H., J.E.K., E.E.B.

Mr. BARNARD remarks on his series of examinations, that nothing was seen which was inconsistent with former observations, or that could not readily be attributed to poor seeing. On March 21, he suspected a slight whitishness on the rings near the shadow, but the seeing was poor, and he places no reliance on this.

Mr. SCHAEBERLE thinks that the contrast between the brightness of the outer and inner portions of Ring *B* is stronger than it appeared in the same telescope several months ago, the shading near the inner edge being now much more marked to him. The other observers do not notice any change.

I therefore conclude that no abnormal appearances on the rings of *Saturn* have been seen at the Lick Observatory on any of the dates of observation by any one of four observers.

Mount Hamilton, 1889 *March* 25.

ELLIPTIC ELEMENTS OF COMET 1888 V (*BARNARD, Oct. 30*),

BY REV. GEORGE M. SEARLE.

Having received, through the kindness of Mr. WENDELL, of Harvard College Observatory, three observations of this comet, made on Feb. 28, Mar. 1, and Mar. 7, I constructed a normal place for Mar. 3.0 Greenw. M.T.; also one from five other observations, for Jan. 1.0, and computed one for Nov. 1.0 from WINLOCK's orbit, published in *Astronomical Journal*, No. 187. This agreed to 1″ with the place computed for the same date from my own orbit in the same number.

These three places gave a parabolic orbit with the following (O—C) residuals:

$$\Delta\lambda = +2'\ 46'' \quad , \quad \Delta\beta = -15''.$$

From the movement of the comet, on Jan. 1, principally in β, and making a large angle with the circle joining its place with that of the sun, it would seem that changing ν would chiefly affect the latitude, and therefore not produce an agreement; and in fact by taking the indicated value, 0.00173, for B_t, I obtained an orbit representing the middle place to

$$\Delta\lambda = +4'' \quad , \quad \Delta\beta = +7''.$$

It appeared, however, on comparison of this orbit with observations of Nov. 11, 21, Jan. 27, and Feb. 18, that an average correction of $+14''$ in λ was indicated; the value of B_t was therefore increased, and another elliptic orbit obtained. Following are the three orbits, for equinox 1888.0; in the third the value of $\log \nu$ was also varied.

T	Sept. 12.9608	Sept. 12.7864	Sept. 12.7711
☊	137 32 53	137 32 5	137 31 48
ω	291 9 17	290 50 7	290 46 57
i	56 33 18	56 22 41	56 20 51
$\log q$	0.186302	0.184358	0.183996
φ		82° 43′ 17″	82 21 20
Period		2613 years	2253 years.

The third gives the residuals $\Delta\lambda = -15''$ $\Delta\beta = -5''$.

The two elliptic orbits represent the other observations, as follows (O—C):

	Nov. 11 Wash.	Nov. 11 Lick	Nov. 21 Wash.	Jan. 27 Wash.	Feb. 18 Wash.
$\Delta\lambda$	+10″	+3″	+15″	+19″	+25″
	+ 4″	−3″	+ 4″	+ 8″	+22″
$\Delta\beta$	− 3″	+6″	+ 9″	+20″	+19″
	− 4″	+3″	+ 4″	+ 9″	+11″

The residuals for my own observation of Dec. 13 are

$$\Delta\lambda,\ -8'',\ -24''; \quad \Delta\beta + 13'',\ +4'';$$

showing an error in λ in that observation which explains the comparatively short period deduced from it.

It seems probable that the normal places of Jan. 1 and

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Mar. 3 will both require a positive correction in λ, owing to errors either of computation or observation. There appears, however, to be little doubt of a period of about 2000 years.

The following ephemeris has been calculated from the parabolic orbit previously used, as the comet will still be visible with large telescopes; corrections of -18^s in α and $+2'.0$ in δ being applied, as indicated by comparison of this with the place resulting from the third orbit above, on April 14.

EPHEMERIS FOR GREENWICH MIDNIGHT (1889.0).

1889	α	δ	log Δ	Brightn.
	h m s	° ′		
Apr. 2	9 20 37	+37 2.9	0.3846	0.16
6	21 3	17.7	4005	.15
10	21 52	28.8	4161	.13
14	23 3	36.7	4318	.12
18	24 34	41.7	4461	.11
22	26 23	44.2	4604	.10
26	9 28 28	+37 44.6	0.4743	0.09

SUMMARY OF SOLAR OBSERVATIONS

AT THE SHATTUCK OBSERVATORY, OF DARTMOUTH COLLEGE, IN 1888,

BY EDWIN B. FROST (Instructor in charge).

1888	Days Observed	No. of Groups	No. of Spots	No. of New Groups	No. of New Spots	Days Observed	No. of Prominences
Jan.	3	4	7	2	7	1	1
Feb.	3	3	10	3	10	1	2
Mar.	3	3	9	2	8	0	
Apr.	7	6	12	3	8	1	1
May	10	4	20	1	8	2	0
June	10	8	40	3	16	3	4
July	6	3	7	3	7	3	3
Aug.	2	1	1	0	0	0	
Sept.	10	10	35	3	6	6	7
Oct.	12	4	13	2	9	8	10
Nov.	15	14	57	2	16	7	1
Dec.	9	5	16	2	11	1	0
	90	65	227	26	106	33	29

The observations are made by projecting an image of eight inches diameter upon a blank form of paper, which is carefully oriented before the spots are drawn. The time was usually within about an hour before or after noon.

The telescope is the 9.4-inch Clark equatorial, and the eye-piece is of power 50. Any unusual phenomena are studied with the Merz helioscope.

"New," as applied to groups and spots, indicates that they have not been observed before, thus showing the number that have been developed on the solar surface, as seen here.

No remarkable prominences have been observed during the year; none have been seen much higher than 1′, and those lower than 10″ or 12″ are not included in the list above.

The observations seem to indicate that the prominences, as well as spots, are nearly at a minimum.

Hanover, N. H., 1889 *April* 4.

OCCULTATION OF *JUPITER*,

OBSERVED AT THE OBSERVATORY OF COLUMBIA COLLEGE.

On Sunday morning, March 24, my assistant and I made the following observations of the occultation of *Jupiter*.

Phenomena	Object Glass	Magn. Power	Columbia College Mean Time	Observer
			h m s	
1st cont.	13 in.	113	Mar. 23 18 52 49.1	J. K. Rees
1st cont.	4 "	38	18 52 47.2	L. H. Jacoby
2d cont.	13 "	113	18 54 48.2	J. K. Rees
2d cont.	4 "	38	18 54 47.5	L. H. Jacoby

The third and fourth contacts were lost in clouds.

The definition during first and second contacts was very fair.

The times were recorded by chronograph, and the clock-error was determined by star-transits March 24.

J. K. REES, *Director*.

Observatory of Columbia College, New York City, 1889 *April* 2.

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OCCULTATION OF *JUPITER*, 1889 MARCH 23,

The following observations of the occultation of *Jupiter* were made at the Haverford College Observatory by Mr. F. W. Peirson. They are in Haverford mean time.

	h m s
First contact,	18 44 9.1
Second "	18 46 8.6
Third "	19 44 24.2

Haverford College, 1889 *March* 26.

Light clouds were present during the greater part of the occultation. No satellites were visible, and *Jupiter* itself was very faint.

F. P. Leavenworth, *Director*.

DISCOVERY OF A COMET, MARCH 31,

By E. E. BARNARD, Astronomer of the Lick Observatory.

On the evening of March 31, at 8ʰ, I discovered with the 12-inch equatorial, a very small and extremely slender comet, the head not being over 10″ in diameter, with a tail at least 15′ long. In the head was an extremely small star-like nucleus of the 13th magnitude. The comet was faintish, less than 12ᴹ.

On April 1, the tail was certainly two times as broad, and much diffused. I could then trace it for only 10′. I thought the comet somewhat brighter.

April 2, as on April 1, except that bad seeing prevented the nucleus being visible.

I send the observations so far obtained.

Lick Observatory, 1889 *April* 3.

Mr. Schaeberle has telegraphed the following elements and ephemeris, obtained from observations March 31, April 2 and 5; but regards the orbit as very uncertain.

T = May 26.44 Gr. M.T.
ω = 348° 37′
Ω = 297 26
i = 90 0
q = 0.0404

Ephemeris for Greenwich Mean Midnight.

1889	α	δ	Brightn.
	h m s	° ′	
April 4	5 17 56	+15 59	1.10
8	5 15 8	15 50	
12	5 12 48	15 41	
16	5 10 48	+15 32	1.62

FILAR-MICROMETER OBSERVATIONS OF COMET *b* 1889 (*BARNARD, March 31*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

By E. E. BARNARD.

1889 Mt. Hamilton M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
March 31 8 31 33	1	10 , 6	+0 37.88	—0 10.7	5 20 51.37	+16 7 3.6	9.6138	0.6107
31 9 53 7	1	8 , 6	+0 34.98	—0 18.1	5 20 48.47	+16 6 56.2	9.6794	0.6730
April 1 7 48 8	1	20 , 7	—0 11.03	—2 19.6	5 20 2.44	+16 4 54.7	9.5563	0.5809
1 8 53 9	1	12 , 7	—0 13.27	—2 26.2	5 20 0.20	+16 4 48.1	9.6415	0.6294
2 8 31 13	1	18 , 7	—1 0.78	—4 34.7	5 19 12.68	+16 2 39.6	9.6253	0.6180

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
1	5ʰ 20ᵐ 14ˢ.30	—0ˢ.83	+16° 7′ 19″.5	—5″.2	Weisse's Bessel V, 519 (mean of two places)

Position-angles of tail: April 1, 9ʰ, 75°.3 (3 obs.) April 2, 9ʰ, 76°.5 (3 obs.)

OBSERVATIONS OF COMET *b* 1889 (*BARNARD, March 31*),

MADE WITH THE 12-¼ INCH EQUATORIAL OF THE DETROIT OBSERVATORY,

By W. W. CAMPBELL.

1889 Greenwich M.T.	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
April 4 15 5 8	1	8 , 7	—0 50.12	+4 21.2	5 17 44.99	+15 58 43.2	9.646	0.722
6 14 32 20	2	12 , 11	—3 4.16	+3 48.3	5 16 22.86	+15 54 39.4	9.633	0.708

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Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	5 18 35.99	—0.88	+15 54 27.4	—5.4	11ᴹ(10 comp. with Newcomb 260)
2	5 19 27.92	—0.90	+15 50 56.5	—5.4	11ᴹ(12 " " " 260)

April 4. Slight moonlight and haze; observation difficult. April 6. Moonlight; comet very faint.

Ann Arbor, 1889 *April* 8.

DISCUSSION OF THE COMET 1882 II.

Untersuchungen über das Cometensystem 1843 I, 1880 I *und* 1882 II. *I Theil. Der grosse September Comet*, 1882 II. *Von* Dr. HEINRICH KREUTZ, Kiel, 1888.

This memoir, published by the Observatory in Kiel, under the direction of Dr. KRUEGER, treats of the second of the remarkable group of comets, with which the comet 1887 I should now probably be counted, and which, following nearly the same orbit, are notable for their peculiar aspect and exceptionally small perihelion-distance.

Dr. KREUTZ's thorough and eminently successful investigation of the difficult problem which this singular comet presents, was published some months since, and should have received earlier notice in this Journal; yet an abstract of his researches and their results, prepared long since, has been deferred from one number to another at the last moment, by the reception of articles or announcements requiring immediate publication. Meanwhile summaries of these researches have appeared in most of the leading astronomical periodicals, and the importance of the results has been universally recognized.

The exceptional obstacles to any accurate computation, which are due to the disintegration of the comet's nucleus and the consequent formation of a line of segregated nuclei, seem to have been most skilfully surmounted.

All available observations have been utilized to the utmost, and, from the time when the original nucleus was replaced by the line of bright points, the relative positions of these points have been determined with all possible care. Dr. KREUTZ has adopted the second of the six nuclear points, counted from the comet's apex, as most nearly representing the probable center of gravity of the whole body; and to this he has referred all the observations. This was the brightest of the points during the first half of the comet's visibility, although the third became equally bright at the close of December, and subsequently surpassed it.

At present we restrict ourselves to reproducing the final elements deduced by Dr. KREUTZ.

EPOCH OF OSCULATION, 1882 SEPT. 20.5, BERLIN M.T.

$$T = 1882\ \text{Sept.}\ 17.2612428 \pm 0.0000319\ \text{Berl. M.T.}$$

$$\left.\begin{aligned} \omega &= 69°\ 35'\ 20''.80 \pm 7''.57 \\ \Omega &= 346\ \ 0\ 42\ .70 \pm 7\ .31 \\ i &= 141\ 59\ 44\ .63 \pm 1\ .79 \end{aligned}\right\}\ \text{M. Eq. 1882.0}$$

$$\begin{aligned} \log q &= 7.8893666 \pm 0.0000364 \\ \log e &= 9.9999600 \pm 0.0000001 \\ e &= 0.9999078 \pm 0.0000002 \\ \log a &= 1.9251 \\ a &= 84^{\text{y}}.16 \pm 0^{\text{y}}.22 \\ \text{Period} &= 772\ .0 \pm 2\ .9 \end{aligned}$$

The computation of the orbit of comet 1880 I has for some time been finished, but Dr. KREUTZ delays its publication until the completion of Dr. WEISS's determination of that of 1843 I.

G.

NOTICE.

A private communication from Professor AUWERS states that the date of the biennial meeting of the *Astronomische Gesellschaft* has been fixed for Tuesday, September 10, and the two following days, at Brussels.

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THE

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THE ORBIT OF THE PLANET *SAPPHO* (80), THE SECULAR PERTURBATION OF THE MINOR PLANETS UPON THE ELEMENTS OF THAT ORBIT, AND THE MASS OF THE PLANET *JUPITER*,

BY ROBERT BRYANT.

During the last four years I have been engaged in determining the orbit of the planet *Sappho*, and as part of my work may be of use in future investigations, and as some points of interest attach to my results, I communicate the following.

The object which I had primarily was to obtain fairly accurate elements of the orbit, so that preparations might be made for the requisite observations in the autumn of the present year, when the planet will be observed to obtain its parallax. I have, however, exceeded my original intention, and have endeavored to make the discussion of the observations as complete as possible.

The values of the perturbations were obtained by the method of Variation of Constants. The interval adopted was 20 days for *Venus*, and 40 days for the *Earth*, *Mars*, *Jupiter* and *Saturn*. When *Mars* was at a considerable distance from *Sappho*, the differentials of the perturbations due to *Mars* were sometimes obtained at intervals of 80 days, the requisite quantities for the intermediate dates being obtained by interpolation. An inspection of the values of the perturbations by *Mars* shows that this course is allowable. The secular effect of *Mercury*, *Uranus* and *Neptune*, was taken into account, the periodic perturbation in the motion of *Sappho* due to these planets being omitted. This secular effect is, however, so small that its omission would have had very little influence upon the result.

The fundamental elements osculating at the epoch are

Epoch 1872 Sept. 7.0 Greenwich mean time.

$$\left.\begin{aligned} L &= 41^\circ\ 20'\ 34''.88 \\ \pi &= 355\ \ \ 0\ \ 38\ .27 \\ \Omega &= 218\ \ 33\ \ \ 8\ .31 \\ i &= 8\ \ 36\ \ 57\ .21 \end{aligned}\right\}\ \text{Mean equinox and ecliptic 1870.0}$$

$$\varphi = 11\ \ 32\ \ 18\ .65$$

$$\mu = 1020''.12879.$$

These elements were obtained from the observations at the oppositions of the planet in 1872, 1877, 1878 and 1882, by Dr. LEMAN, who mentioned to the writer that they did not well represent the earlier observations of the planet.

The following masses of the planets were adopted:

Mercury	1 : 7636440	*Jupiter*	1 : 1047.879
Venus	1 : 401839	*Saturn*	1 : 3501.6
Earth	1 : 355499	*Uranus*	1 : 22000
Mars	1 : 3076135	*Neptune*	1 : 19700

Adopted value of the sun's parallax 8″.848

The perturbations at the following selected dates are for Greenwich mean noon, and are referred to the mean equinox and ecliptic of 1870.0.

ΔL_1 denotes the change in the mean longitude of the epoch.

ΔL_2 denotes the change in the mean longitude due to perturbation of the mean motion.

The adopted elements were corrected for the effect of perturbation every 40 days.

Venus.

	ΔL_1	ΔL_2	$\Delta\pi$	$\Delta\Omega$	Δi	$\Delta\varphi$	$40\Delta\mu$
	″	″	″	″	″	″	″
1864 May 12	−16.69	+43.08	+ 4.76	+1.00	−0.07	+1.65	−0.2384
1865 Nov. 23	−12.81	+34.47	+ 3.33	+1.02	−0.12	+0.17	−0.2993
1867 April 27	−10.13	+27.84	− 0.60	+0.51	−0.26	+1.08	−0.4284
1868 Aug. 19	− 9.32	+21.38	− 0.24	+0.24	−0.26	+3.37	−1.4043
1870 Mar. 2	− 5.80	+13.31	+ 7.11	+0.31	−0.25	−1.30	−0.9997
1871 May 16	− 6.92	+ 8.47	+ 2.13	−0.56	−0.20	−0.06	−0.4221
1873 Jan. 5	− 2.61	− 0.66	+10.39	−1.55	−0.21	+1.86	−0.8991
1874 April 30	− 0.53	− 6.99	+ 7.00	−1.16	+0.04	+0.97	−0.2197
1875 Oct. 2	+ 3.98	−14.63	+ 2.12	−1.30	−0.02	−0.45	+0.1523
1877 Mar. 5	+ 8.51	−22.43	− 0.46	−0.72	−0.11	+1.84	−0.0312
1878 May 19	+10.89	−28.24	− 6.55	−1.21	−0.21	+1.00	−1.0560
1880 Jan. 9	+15.63	−37.53	+ 8.74	−0.70	−0.08	+1.00	−0.6687

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	ΔL_1	ΔL_2	$\Delta\pi$	$\Delta\Omega$	Δi	$\Delta\varphi$	$40\Delta\mu$
	″	″	″	″	″	″	″
1881 May 3	+16.18	−43.29	− 2.78	−1.35	−0.27	+0.09	−1.0266
1882 Oct. 5	+17.31	−50.29	+ 4.27	−1.92	−0.13	+4.26	−1.3321
1885 April 12	+25.24	−64.10	+ 6.10	−1.54	+0.07	+2.57	−0.2849
1887 Jan. 12	+26.17	−72.94	− 0.54	−2.22	−0.02	+2.49	−0.0696
1888 Mar. 27	+31.75	−79.63	+ 4.63	−1.90	−0.10	+2.00	−0.4754

Earth.

	ΔL_1	ΔL_2	$\Delta\pi$	$\Delta\Omega$	Δi	$\Delta\varphi$	$40\Delta\mu$
1864 May 12	−19.07	−33.41	−21.51	+2.40	−0.09	−2.48	−0.0889
1865 Nov. 23	−15.68	−27.10	+ 1.97	+1.98	−0.08	−0.58	−0.2847
1867 April 27	−10.84	−21.54	−15.73	+2.43	−0.14	−3.50	−0.0138
1868 Aug. 19	− 8.62	−16.05	−12.93	+1.53	−0.03	+0.76	−0.3195
1870 Mar. 2	− 2.61	−11.31	− 1.39	+1.22	+0.02	−3.44	−0.0618
1871 May 16	− 1.45	− 5.91	−17.67	+0.38	−0.04	−1.94	−0.1623
1873 Jan. 5	+ 4.25	− 0.68	+ 7.33	+0.11	−0.01	−1.67	−0.2199
1874 April 30	+ 6.94	+ 4.43	−11.27	+0.33	−0.10	−3.24	−0.0805
1875 Oct. 2	+11.19	+ 8.87	− 0.31	−0.61	+0.04	+1.00	−0.3964
1877 Mar. 5	+15.06	+14.98	+ 3.11	−0.63	+0.07	−3.69	+0.0574
1878 May 19	+16.19	+21.67	−12.52	−1.53	+0.02	−1.94	−0.0491
1880 Jan. 9	+21.40	+28.76	+11.45	−1.80	+0.04	−1.89	−0.0906
1881 May 3	+24.30	+35.44	− 7.95	−1.62	−0.05	−3.23	+0.0432
1882 Oct. 5	+28.32	+41.66	+ 4.10	−2.48	+0.08	+0.72	−0.2106
1885 April 12	+32.23	+56.00	− 5.84	−3.37	+0.06	−2.27	+0.1811
1887 Jan. 12	+39.00	+63.87	+15.40	−3.64	+0.10	−1.94	−0.0313
1888 Mar. 27	+40.18	+70.99	− 1.23	−3.65	+0.01	−3.40	+0.1096

Mars.

	ΔL_1	ΔL_2	$\Delta\pi$	$\Delta\Omega$	Δi	$\Delta\varphi$	$40\Delta\mu$
1864 May 12	− 2.97	−12.56	− 2.24	+1.19	+0.02	−0.71	+0.0610
1865 Nov. 23	− 3.17	−10.27	− 1.62	+1.15	+0.05	−0.90	+0.2357
1867 April 27	− 3.25	− 7.80	− 1.18	+1.04	+0.03	−1.09	+0.1306
1868 Aug. 19	− 1.85	− 6.52	− 1.83	+1.04	+0.02	−0.64	+0.1241
1870 Mar. 2	− 2.10	− 3.48	− 2.68	+0.89	+0.04	−0.71	+0.2735
1871 May 16	− 1.98	− 1.11	− 3.17	+0.92	+0.02	−0.94	+0.1669
1873 Jan. 5	+ 0.14	+ 0.03	− 0.19	+0.02	0.00	−0.08	+0.0231
1874 April 30	− 0.21	+ 1.03	− 0.59	−0.12	+0.02	+0.05	+0.0935
1875 Oct. 2	+ 0.28	+ 1.37	− 0.90	−0.20	+0.01	+0.01	+0.0106
1877 Mar. 5	+ 2.87	+ 3.79	+ 1.40	−0.77	−0.04	−1.33	+0.2387
1878 May 19	+ 2.42	+ 6.96	+ 1.60	−0.93	−0.03	−1.23	+0.2828
1880 Jan. 9	+ 2.87	+ 9.75	+ 1.25	−0.92	−0.06	−1.14	+0.1429
1881 May 3	+ 4.14	+12.09	− 0.73	−1.42	−0.04	−1.25	+0.2466
1882 Oct. 5	+ 3.61	+15.67	− 0.70	−1.56	−0.04	−1.26	+0.2464
1885 April 12	+ 5.09	+19.24	− 0.76	−1.72	−0.02	−1.09	+0.1898
1887 Jan. 12	+ 4.46	+23.13	− 0.34	−1.93	−0.04	−1.09	+0.2319
1888 Mar. 27	+ 5.10	+24.99	− 0.55	−1.97	−0.03	−1.27	+0.1499

Jupiter.

	ΔL_1	ΔL_2	$\Delta\pi$	$\Delta\Omega$	Δi	$\Delta\varphi$	$40\Delta\mu$
	′ ″	′ ″	′ ″	′ ″	″	′ ″	″
1864 May 12	+ 3 13.41	+ 5 20.00	+ 1 26.38	+ 2 12.63	− 6.71	+0 23.47	−29.7260
1865 Nov. 23	+ 2 16.81	+ 2 49.03	+ 9 16.22	+ 1 53.01	−10.98	+0 7.61	−13.8179
1867 April 27	+ 0 45.57	+ 0 9.10	+10 53.13	+ 0 47.67	− 7.50	+1 20.01	− 3.6838
1868 Aug. 19	+ 1 17.19	+ 0 53.00	+12 13.70	+ 0 33.36	− 2.80	+2 30.28	− 4.7480
1870 Mar. 2	+ 0 45.06	+ 1 24.75	+ 2 57.57	+ 0 20.78	+ 4.70	+2 4.60	+ 9.8584
1871 May 16	+ 0 33.45	+ 1 23.17	+ 0 59.38	+ 0 27.52	+ 0.46	+0 48.45	− 9.4912
1873 Jan. 5	+ 0 14.57	− 0 5.81	+ 1 44.70	− 0 10.14	− 1.38	−0 4.47	− 5.5067
1874 April 30	− 5 6.27	− 5 44.50	+20 27.77	− 6 2.13	+30.32	−0 3.00	−26.1031
1875 Oct. 2	− 5 16.18	− 6 51.10	+27 44.64	− 6 4.96	+41.30	+1 12.37	− 5.0175
1877 Mar. 5	− 6 1.19	− 7 46.51	+23 54.88	− 6 18.93	+41.13	+2 0.37	+ 4.3846
1878 May 19	− 4 50.96	− 6 16.91	+19 47.60	− 6 31.55	+40.00	+2 29.54	+ 2.0837
1880 Jan. 9	− 5 55.10	− 7 18.38	+13 56.15	− 8 39.65	+38.45	+1 16.32	− 0.8986
1881 May 3	− 7 12.73	− 9 48.59	+19 16.56	− 9 17.29	+40.68	+0 24.04	−19.8957
1882 Oct. 5	− 8 7.24	−12 46.51	+23 29.31	− 9 24.36	+40.73	−0 20.42	− 4.7008
1885 April 12	−10 39.24	−16 26.58	+24 7.12	−14 40.73	+39.91	+4 28.95	+ 8.4801
1887 Jan. 12	−11 1.56	−15 55.05	+18 21.13	−14 55.19	+41.24	+4 36.00	+ 7.5148
1888 Mar. 27	− 9 58.46	−14 45.90	+15 21.00	−14 51.99	+40.54	+3 19.08	− 6.6949

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Saturn.

	ΔL_1	ΔL_2	$\Delta\pi$	$\Delta\Omega$	Δi	$\Delta\varphi$	$40\Delta\mu$
	″	″	″	″	″	″	″
1864 May 12	+ 7.57	—3.74	+19.92	+ 3.61	+0.27	+5.56	—0.0040
1865 Nov. 23	+ 6.87	—1.99	+19.43	+ 3.70	+0.43	+7.51	+0.0780
1867 April 27	+ 8.67	+1.85	+ 8.95	+ 3.74	+0.48	+4.22	—0.2279
1868 Aug. 19	+ 2.95	—1.49	+20.94	+ 3.47	+0.44	—0.20	+0.2314
1870 Mar. 2	+ 0.58	—2.13	+14.81	+ 2.59	+0.37	+3.08	+0.2487
1871 May 16	+ 2.55	+0.97	+ 0.20	+ 2.25	+0.15	+2.42	—0.2010
1873 Jan. 5	— 0.68	—0.44	+ 3.37	— 0.46	—0.07	+0.53	—0.2699
1874 April 30	— 3.90	—2.10	+ 7.02	— 3.63	+0.12	+4.12	+0.3009
1875 Oct. 2	— 4.52	—0.44	— 7.51	— 6.51	+0.13	+4.46	—0.0137
1877 Mar. 5	— 5.84	—0.33	+ 5.77	— 9.20	+0.16	+3.24	—0.4232
1878 May 19	— 9.40	—2.27	+21.73	—10.74	+0.65	+5.01	+0.3163
1880 Jan. 9	—10.09	+0.20	+ 5.78	—11.71	+0.96	+5.66	+0.4761
1881 May 3	—12.21	—0.08	+17.87	—13.24	+1.12	+1.79	—0.4941
1882 Oct. 5	—14.48	—1.02	+33.83	—13.04	+1.23	+1.33	+0.0212
1885 April 12	—17.03	+0.32	+ 0.85	—13.26	+0.98	+0.57	—0.3479
1887 Jan. 12	—21.44	—1.43	+17.52	—16.81	+0.57	+0.36	—0.8309
1888 Mar. 27	—25.49	—2.84	+10.65	—24.67	+0.91	+8.07	+0.6504

In the formation of the normal places of the planet no comparison-star was employed whose adopted place depends upon less than 3 observations. LALANDE's places have not been used. The average number of observations of each comparison-star is 10.

The following normal places referred to the mean equinox and ecliptic of 1870.0, and expressed in longitude and latitude, were obtained.

	Greenwich M.T.	λ		Wt.	No. Obs.	β		Wt.	No. Obs.
		° ′ ″				° ′ ″			
1	1864 May 22.0	239 39 19.04	±0.45	2	21	+ 5 35 13.70	±0.59	1	20
2	1865 Dec. 13.0	91 7 17.95	±0.44	2	11	—11 28 24.36	±0.80	1	11
3	1867 April 7.0	189 57 34.66	±0.81	1	16	— 5 58 12.86	±0.54	1	17
4	1868 Aug. 29.0	345 35 48.53	±0.43	2	34	+16 3 31.25	±0.32	2	28
5	1868 Sept. 12.0	340 28 15.43	±0.28	2	31	+14 56 26.25	±0.42	2	24
6	1870 Feb. 20.0	148 18 20.85	±1.71	1	26	—12 40 47.00	±1.70	1	24
7	1871 May 20.0	247 16 48.35	±0.19	3	12	+ 6 23 39.84	±0.11	4	13
8	1875 Sept. 22.0	352 38 12.15	±0.62	1	10	+12 44 1.12	±0.32	2	10
9	1882 Sept. 15.0	8 52 29.07	±0.11	4	37	+11 34 55.06	±0.10	4	36
10	1882 [illegible] 5.0	4 21 59.85	±0.11	4	37	+ 9 21 52.52	±0.08	4	36
11	1887 [illegible] 20.0	103 12 26.21	±0.26	3	40	—13 33 50.26	±0.18	3	34
12	1888 April 16.0	201 59 16.54	±0.21	3	53	— 3 29 26.53	±0.10	4	52
13	1872 Dec. 26.0	95 21 21.53		$\frac{3}{4}$	4	—12 35 45.44		$\frac{3}{4}$	4
14	1877 Mar. 15.0	147 36 29.50		$\frac{3}{4}$	2	—11 24 58.49		$\frac{3}{4}$	2
15	1878 June 6.0	249 48 10.58		$\frac{3}{4}$	4	+ 8 35 40.59		$\frac{3}{4}$	4
16	1880 Jan. 22.0	96 1 15.00		$\frac{3}{4}$	2	—13 3 21.55		$\frac{3}{4}$	2

"No of obs." signifies the number of observations in R.A. and Decl. respectively.

The 2 observations in 1880 were made in the meridian at Washington, and there was some doubt as to whether it was the planet that was observed. The observed places agree very closely with the computed places of *Sappho*, and there is a high degree of probability that it was the planet that was observed.

A rough calculation to obtain preliminary corrections was made from the longitudes of 1864, 1868 (ii), 1875, 1880 and 1888, and from the latitudes of 1864, 1875 and 1888.

Whence

$$\delta L = +5.''09 \qquad \delta i = +1.''73$$
$$\delta\pi = +12.92 \qquad \delta\varphi = -2.97$$
$$\delta\Omega = +22.16 \qquad \delta\mu = -0.01100$$

The first 12 normal places were then chosen for the deduction of the final corrections of the elements. The requisite equations, having been solved by the method of least squares, gave $[nn6] = 1.24722$ and $[ns6] = 1.24722$. The following residuals were obtained (Obs.–Comp.):

		$\delta\lambda\cos\beta$	$\delta\beta$
		″	″
1	1864	— 8.91	+2.17
2	1865	—11.65	+3.10
3	1867	—22.38	—5.85
4	1868(i)	+13.21	+0.19
5	1868(ii)	+14.99	—0.98
6	1870	—18.45	—0.22
7	1871	— 5.53	+2.07
8	1875	+ 3.35	—2.90
9	1882(i)	— 6.91	+1.77
10	1882(ii)	— 7.23	+1.45
11	1887	+18.29	+1.72
12	1888	+12.95	+1.19

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Also

$$\delta L = +\overset{''}{2.47} \qquad \delta i = -\overset{''}{0.04}$$
$$\delta\pi = +13.02 \qquad \delta\varphi = +5.26$$
$$\delta\Omega = -10.27 \qquad \delta\mu = -0.00081$$

As an incorrect value of *Jupiter's* mass might perhaps account for part of these large errors, a term was introduced to correct the adopted mass of that planet. The sum of the squares of the residuals then fell to less than half its original amount, but the deduced value of the mass of *Jupiter* was about $\frac{1}{1030}$, which is inadmissible.

We have, then, to seek the cause of these large residuals. As we have eliminated the effect of all the disturbing planets, except that of the minor planets, the cause which suggests itself is the mutual perturbation of the minor planets.

The residuals for the 4 unemployed normal places are

		$\delta\lambda \cos\beta$	$\delta\beta$
		$''$	$''$
13	1872	—28.20	—4.22
14	1877	— 7.95	—5.51
15	1878	+18.77	+5.01
16	1880	—28.89	+7.83

Now, the periodic time of *Sappho* is almost exactly $3\frac{1}{2}$ years. Consequently, after the lapse of 7 years, each opposition of the planet occurs with the *Earth* and *Sappho* very nearly in the same position that they occupied 7 years previously, and thus in our investigation with the 12 normal places we have employed no new part of the orbit between 1871 and 1882. Introducing, therefore, the normal places for 1872, 1877, 1878 and 1880, we get 32 equations of condition, and solving these on the supposition that the adopted mass of *Jupiter* is correct, the sum of the squares of the residuals is reduced from 5830″ to 5480″, so that very little improvement is effected.

[We take $\quad (\phi) = e \sin\pi \quad$ and $\quad (\psi) = e \cos\pi$]

Terms were then introduced to determine the secular change in each element (except in μ). It was then found that the introduction of one secular term only, viz.: that in (ϕ), reduced the sum of the squares of the residuals from 5480″ to 1960″. This great reduction evidently shows that the disturbing action of the minor planets upon *Sappho* is not only sensible, but that it must be taken into account in an accurate determination of the orbit.

The secular variation of the mean longitude rapidly confounds itself with a change in the mean motion. As the equation which gave this secular variation approximated to an indeterminate form, the term was omitted, the requisite correction becoming incorporated in μ.

The following corrections were then found:

$$\delta L = -\overset{''}{3.68} \qquad \delta i = +\overset{''}{0.56}$$
$$\delta\pi = -15.99 \qquad \delta\varphi = -1.62$$
$$\delta\Omega = -1.80 \qquad \delta\mu = +0.00126$$

Secular variation of $\pi = +\overset{''}{274.0}$
" " $\Omega = +58.3$
" " $i = -15.2$
" " $\varphi = +15.7$

Also $\dfrac{\delta J}{J} = -0.000516 \pm 0.0395$

where J = adopted mass of *Jupiter*.

The residuals (observation–computation) then are

	$\delta\lambda \cos\beta$	$\delta\beta$		$\delta\lambda \cos\beta$	$\delta\beta$
	$''$	$''$		$''$	$''$
1864	+1.62	—3.82	1882(i)	— 0.12	+0.91
1865	+8.75	+3.67	1882(ii)	— 0.25	+0.36
1867	—2.88	—3.21	1887	+ 7.76	—0.06
1868(i)	+1.80	—0.70	1888	— 2.56	—0.06
1868(ii)	+0.17	—0.70	1872	—16.40	—4.53
1870	—0.12	+1.75	1877	— 6.09	—5.37
1871	—0.59	+0.87	1878	+15.55	+5.48
1875	+3.32	—2.47	1880	—27.93	+6.79

The sum of the squares of the weighted residuals is 1540″, and to this sum the residuals for 1872, 1877, 1878 and 1880 contribute 1090″. The residuals in longitude for 1865 and 1887 are greater than can be attributed to errors of observation. The normal place for 1872 depends upon one observation at Washington, one at Leipzig, and 2 at Berlin, all the observations being in good agreement. The normal place for 1877 depends upon 2 accordant observations at Madrid, and that for 1878 depends upon 4 accordant observations at the same place. It is impossible to admit that the large residuals for 1872 and 1878 are due to errors of observation.

With regard to the normal place for 1880, it depends upon two meridian observations at Washington of an object which was supposed to be *Sappho*. The observations are in fair agreement, and considering the magnitude of the resulting residual, it is highly probable that the planet was the object observed. Evidently, then, there is still some other disturbing cause which we have not considered, and this is most probably the periodic perturbation of the minor planets. The small weight assigned to the normal places for 1872, 1877, 1878 and 1880, causes the effect of the omission of the periodic perturbation to be most evident in these places. Of course, part of the error is due to the small corrections of the elements which are still required, for if we took into account the periodic perturbation the adopted elements would be changed slightly.

It may be noticed that the large residuals for 1865, 1872, 1880 and 1887, occur in the same part of the orbit at an interval of 7 years.

We have made three sets of corrections to the adopted elements, and the sum of these will of course be the finally adopted correction. This sum is

$$\delta L = +\overset{''}{3.88} \qquad \delta i = +\overset{''}{2.25}$$
$$\delta\pi = +9.95 \qquad \delta\varphi = +0.67$$
$$\delta\Omega = +10.09 \qquad \delta\mu = -0.01055$$

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The change in the mean motion seems large, but this is due to the fact that the secular action of *Venus*, the *Earth*, and *Mars* upon the mean longitude (which is here given separately) had been incorporated with the mean motion when the fundamental elements were determined.

It should be borne in mind that changes in π and ☊ must be multiplied by $\sin\varphi(=\frac{1}{5})$ and $\sin i(=\frac{1}{7})$ respectively to see their effect upon the geocentric place.

The above corrections are then very small. In other words, Dr. LEMAN's elements are nearly correct, and we now see why he was unable to represent the earlier observations of the planet, although his elements were correct.

Finally, then, we have for our fundamental elements referred to the mean equinox and ecliptic of 1870.0.

EPOCH 1872 SEPT. 7.0 GR.M.T.

	° ′ ″	″	″
L	41 20 38.76	± 2.53	or ±0.65
π	355 0 48.22	±11.02	±2.29
☊	218 33 18.40	± 3.57	±3.55
i	8 36 59.46	± 0.54	±0.53
φ	11 32 19.32	± 0.41	±0.25
μ	1020″.11824	±0.00567	±0.00015

		″	″	
Annual variation of	π	+2.740	±0.478	±0.240
" "	☊	+0.583	±0.740	±0.670
" "	i	−0.152	±0.112	±0.112
" "	φ	+0.157	±0.094	±0.047

The probable error of $\frac{\delta J}{J}$, the correction of *Jupiter's* mass exceeds the amount of the correction itself, and a like remark applies to the secular variation of the node. The uncertainty of the correction of *Jupiter's* mass communicates itself to the probable errors of the remaining quantities. Accordingly, as we do or do not apply this correction to *Jupiter's* mass, we get the first or the second set of the probable errors given above.

The value of *Jupiter's* mass resulting from this investigation is $\frac{1}{1048.42}$, the sun's mass being taken as unity.

The effect of introducing a secular term in the mean motion was tried, but the results were not very satisfactory. It was found that

$$\tfrac{1}{2}\frac{\delta\mu}{\delta t} = +0''.000000292 \pm 0''.000000231$$

and the sum of the squares of the residuals falls to 1871″. For a better representation, however, of the normal places, we must probably look to the periodic perturbation of the minor planets, rather than to the action of the hypothetical ether.

If the action of the minor planets upon one another be so great as it seems to be from this investigation, then it is probable that their action upon the motion of the planet *Mars* is also sensible, and we may, perhaps, here see some explanation of the errors of LEVERRIER's tables of *Mars* that were found by Dr. GILL in his heliometer observations of that planet in 1877.

It has been objected that the secular terms found above might be produced by an incorrect value of the adopted masses of the planets. This, however, is impossible. For such terms could not arise from the action of *Jupiter*, as we have already introduced a term to correct the adopted mass of that planet. If we, then, attribute these secular terms to the action of any of the other planets, we shall have to change their adopted masses by quantities which are out of the question.

If an investigation, similar to that here employed for *Sappho*, were carried out for each of the minor planets, we might obtain sufficient material for the determination of the masses of these small bodies; but the labor would be enormous.

In the autumn of the present year the planet will make a close approach to the earth, the minimum distance being less than 0.862, so that a very favorable opportunity will be afforded of determining the sun's parallax. This will be effected by the heliometer, but it is greatly to be desired that photography should also be applied for the determination of the above important quantity. In England, Messrs. PRITCHARD, COMMON and ROBERTS have expressed their willingness to take part in the work. If photographs be obtained in England, at the Cape of Good Hope, in Australia, at the Lick Observatory and on the eastern coast of America, there will be ample material for a very accurate determination of the sun's parallax. One year is, in general, no more favorable for the determination of stellar parallaxes than another, but the case is otherwise when we deal with the parallax of a planet. It will, therefore, be a matter of great regret if the next opposition of *Sappho* is allowed to pass without a determination of that planet's parallax by means of photography.

Postscript. I have just received a letter from Dr. GILL of the Cape of Good Hope, dated 1889 March 8. From the letter it seems probable that the new 13-inch photographic telescope, now in the hands of Sir Howard GRUBB, will be mounted in time, and Dr. GILL says, "in that case we shall cooperate in observing *Sappho* photographically." "In any case," he continues, "I should recommend the photographic observation of the planet by any of those observatories for which the new photographic telescopes have been completed. If the photographs are taken at such an hour-angle (this will be about 3^h to 4^h east and west of the meridian) as will make the line joining the planet and a pair of comparison-stars nearly vertical, then it will be quite possible to combine the photographic observation with the heliometer observation, and I will gladly deal with the measurement and reduction of such plates. It is essential, however, that every observatory which takes part in photographing the planet should be provided with a *reseau*, the errors of which have been determined at Potsdam or elsewhere, and that the image of this *reseau* should be impressed on the plates before they are exposed in the telescope. It will then be possible to combine the heliometer and photographic observations with all requisite rigidity.

* * * * * * * * * * * * *

"I think we have certainly got a sufficiency of heliometer observations of *Iris* to get a solar parallax, with a probable error of ±0″.015, and if we do the same by *Victoria* and *Sappho* in the current year, the question may be considered determined."

Royal Astronomical Society, London.

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OCCULTATION OF *JUPITER*, MARCH 23,

BY EDWIN B. FROST.

With the 9.4-inch equatorial I made the following observations, in Hanover M.T.:

	h	m	s
First contact	19	5	35.1
Planet half obscured	19	6	36.7
Disappearance of 4th satellite	19	14	0
Fourth contact	19	55	29

Dartmouth College, 1889 *April* 22.

The second contact was lost, but the planet had disappeared at $19^h\ 7^m\ 43^s$.

A magnifying power of 50 was used, except in the case of satellite, when a power of 110 was substituted.

The observations were recorded by chronograph, and the clock-error was determined on the previous evening.

The daylight made the observations rather difficult, especially in the case of the satellite.

ELEMENTS AND EPHEMERIS OF COMET *c* 1888,

BY PROF. C. W. CROCKETT.

The elements were computed from the following places: A normal place for Sept. 6.0, formed from 13 observations (3 at Madison, 4 at Mt. Hamilton, 3 at Albany, 1 at Königsberg, 2 at Besançon), made Sept. 4, 5 and 6; 2 Albany observations, approximating the date Oct. 18.7; 3 Albany observations, approximating Nov. 1.8; and 2 Albany observations, approximating Dec. 12.6. The adopted places of the comet, referred to the mean equinox of 1888.0, for the respective dates corrected for aberration, are:

Date	α 1888.0 (° ′ ″)	δ 1888.0 (° ′ ″)
Sept. 6.0	102 59 12.9	+10 47 54.3
Oct. 18.7373	92 31 53.4	+ 5 56 23.2
Nov. 1.7947	80 30 10.8	+ 2 38 23.7
Dec. 12.5660	19 15 23.4	— 7 32 53.8

From these, the following elements were derived:

$$T = 1889 \text{ January } 31.20929$$

$$\left.\begin{aligned} \omega &= 340^\circ\ 28'\ 39''.6 \\ \Omega &= 357\ \ 25\ \ 21\ .2 \\ i &= 166\ \ 22\ \ 12\ .6 \end{aligned}\right\} 1889.0$$

$$\log q = 0.258823$$

The reductions to 1888.0 are:

$$\Delta\omega = -0''.15, \quad \Delta\Omega = -50''.40, \quad \Delta i = -0''.49.$$

The residual differences (C—O) are:

	Sept. 6.0	Oct. 18.7	Nov. 1.8	Dec. 12.6
	″	″	″	″
$\cos\beta\,\Delta\lambda$	—0.1	—3.4	+3.3	+0.1
$\Delta\beta$	0.0	—0.4	—1.9	0.0

The equations for the heliocentric coordinates for 1889.0 are

$$\begin{aligned} x &= r[9.999976] \sin(\ 72^\circ\ 58'\ 57''.4+v) \\ y &= r[9.993568] \sin(162\ 52\ 38.3+v) \\ z &= r[9.233418] \sin(166\ 28\ 47.4+v) \end{aligned}$$

The mean of 5 Washington observations, approximating the mean date Jan. 31.3, gives as the correction to an ephemeris computed from the above equations: $\Delta\alpha = -0^s.72$, $\Delta\delta = -6''.1$. A comparison with a normal place of mean date Jan. 31.5, formed from 7 Rome observations by A. BERBERICH (*A.N.* 2883), gives: $\Delta\alpha = -0^s.74$, $\Delta\delta = -0''.9$. Following is the

EPHEMERIS FOR GREENWICH MIDNIGHT.

1889	App. α (h m s)	App. δ (° ′ ″)	log r	log Δ	Br.
April 19.5	23 30 33.0	+0 47 17	0.31520	0.44452	1.7
20.5	30 12.2	0 51 13			
21.5	29 50.6	0 55 6	0.31770	0.44166	1.7
22.5	29 28.1	0 58 57			
23.5	29 4.6	1 2 46	0.32022	0.43860	1.7
24.5	28 40.1	1 6 32			
25.5	28 14.6	1 10 16	0.32278	0.43535	1.7
26.5	27 48.1	1 13 57			
27.5	27 20.4	1 17 36	0.32536	0.43190	1.7
28.5	26 51.7	1 21 12			
29.5	26 21.8	1 24 45	0.32796	0.42826	1.7
30.5	25 50.7	1 28 15			
May 1.5	25 18.4	1 31 42	0.33058	0.42442	1.7
2.5	24 44.8	1 35 6			
3.5	24 9.9	1 38 26	0.33322	0.42040	1.7
4.5	23 33.7	1 41 43			
5.5	22 56.0	1 44 57	0.33588	0.41620	1.7
6.5	22 16.9	1 48 6			
7.5	21 36.4	1 51 12	0.33856	0.41181	1.7
8.5	20 54.3	1 54 14			
9.5	20 10.6	1 57 12	0.34126	0.40724	1.7
10.5	19 25.4	2 0 6			
11.5	18 38.5	2 2 55	0.34397	0.40251	1.8
12.5	17 49.8	2 5 39			
13.5	16 59.5	2 8 19	0.34669	0.39761	1.8
14.5	16 7.4	2 10 54			
15.5	15 13.4	2 13 24	0.34943	0.39254	1.8
16.5	14 17.6	2 15 49			
17.5	13 19.8	2 18 9	0.35218	0.38732	1.8
18.5	12 20.0	2 20 23			
19.5	11 18.2	2 22 32	0.35494	0.38195	1.9
20.5	10 14.2	2 24 35			
21.5	9 8.1	2 26 31	0.35770	0.37644	1.9
22.5	7 59.8	2 28 21			
23.5	6 49.2	2 30 4	0.36048	0.37079	1.9
24.5	5 36.3	2 31 40			
25.5	4 20.9	2 33 10	0.36326	0.36502	1.9
26.5	3 3.1	2 34 32			
27.5	1 42.8	2 35 47	0.36605	0.35913	1.9
28.5	23 0 19.9	2 36 54			
29.5	22 58 54.4	2 37 52	0.36884	0.35315	2.0
30.5	57 26.2	2 38 42			
31.5	22 55 55.2	+2 39 23	0.37164	0.34709	2.0

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1889	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′ ″			
June 1.5	22 54 21.4	+2 39 55			
2.5	52 44.7	2 40 17	0.37444	0.34096	2.0
3.5	51 5.1	2 40 30			
4.5	49 22.4	2 40 33	0.37724	0.33478	2.1
5.5	47 36.8	2 40 25			
6.5	45 48.0	2 40 7	0.38005	0.32857	2.1
7.5	43 56.1	2 39 38			
8.5	42 1.0	2 38 58	0.38286	0.32236	2.1
9.5	40 2.6	2 38 6			
10.5	38 0.9	2 37 2	0.38567	0.31618	2.2
11.5	35 55.9	2 35 46			
12.5	33 47.5	2 34 17	0.38848	0.31004	2.2
13.5	31 35.8	2 32 35			
14.5	29 20.5	2 30 40	0.39128	0.30398	2.2
15.5	22 27 1.8	+2 28 31			
June 16.5	22 24 39.5	+2 26 8	0.39408	0.29803	2.2
17.5	22 13.7	2 23 31			
18.5	19 44.4	2 20 40	0.39688	0.29222	2.3
19.5	17 11.4	2 17 33			
20.5	14 34.9	2 14 11	0.39968	0.28659	2.3
21.5	11 54.8	2 10 34			
22.5	9 11.2	2 6 41	0.40248	0.28118	2.3
23.5	6 24.0	2 2 32			
24.5	3 33.2	1 58 7	0.40527	0.27604	2.4
25.5	22 0 39.1	1 53 25			
26.5	21 57 41.5	1 48 27	0.40805	0.27120	2.4
27.5	54 40.4	1 43 12			
28.5	51 36.1	1 37 40	0.41083	0.26671	2.4
29.5	48 28.6	1 31 51			
30.5	21 45 18.0	+1 25 46	0.41361	0.26262	2.4

LETTER FROM MR. SCHAEBERLE,

Owing to an error of transcription, the value of q, as given in my dispatch, is slightly in error: it should read $q = 0.04096$ in place of 0.04040.

Since the correction to my ephemeris is not unusually large, I give the constants for the equator, as they may be of use hereafter.

$$x = r[9.66338] \sin(v + 90°)$$
$$y = r[9.95727] \sin(v + 243° 57')$$
$$z = r[9.99250] \sin(v + 338° 56')$$

Lick Observatory, 1889 *April* 19.

THE LUMINOUS NIGHT-CLOUDS.

AN APPEAL FOR OBSERVATIONS OF THEM.

[Translated from the *Astronomische Nachrichten*, and published by request of the Author.]

Since their first appearance in 1885, the luminous night-clouds have annually recurred in the months of June and July. It appears, however, that the importance of those inquiries which may be answered by systematic observation of the phenomenon has hitherto been unrecognized or insufficiently appreciated; for the attention which has thus far been directed to the subject is extremely small.

These luminous night-clouds have not only high meteorological, but almost yet greater astronomical interest; both because they seem capable of affording information on the question whether celestial space is filled with a resisting medium, and because there is some probability that we see in this phenomenon a repetition of occurrence which may have performed and to some extent yet perform an important part in the earlier period of development of our earth and of the planets in general.

I have set forth these ideas in fuller detail in the February number of the periodical "*Himmel and Erde*," and will here recapitulate the most essential points.

The circumstance that the luminous night-clouds exhibit so clearly manifest periodic motion, taken in connection with their extreme altitude (which photographic determinations give as about 75 kilometers) suggests the assumption that there is here a display of the activity of cosmical forces. Considering the position of the Earth's axis in space, relatively to the direction of the Earth's motion around the sun, we recognize at once that the presence of a resisting medium in space may very well so affect the course of the phenomenon that we only see it in Europe during the months of June and July; in which case it would take place during the months of December and January in the zone between about 45° and 60° of south latitude.

It is remarkable that certain appearances on the surface of *Jupiter* seem to indicate that the atmosphere of this planet is similarly filled with the same material which on the Earth gives rise to the luminous night-clouds.

Should this phenomenon of luminous night-clouds, have ceased to manifest itself after the lapse of a few years, it may recur perhaps after some decades, or perhaps only after some centuries, and according to present experience it seems questionable whether it will then fix the attention of observers in a sufficient degree to be made serviceable toward the solution of the highly interesting questions which relate to their origin, their constitution and their periodic motion. *I therefore appeal to all the observatories of the world — as likewise to all meteorological institutes and mariners, asking that they take notice of the phenomenon and communicate to me the results of observation.* Even in the case that the luminous clouds should not be seen in the southern latitudes from about 45° to 60° in the months of December and January, or likewise should they not be seen in the equatorial regions in the months, March to May, and September to November, a communication on the subject will be highly valuable.

With regard to the record of the observations, it is desirable to give the time and place of observation; also the part of the sky in which the phenomenon has been seen, and furthermore its approximate extent. The time should be noted to within a few minutes, and the geographical latitude and longitude of the place to within a few minutes of arc. Furthermore, any other information as to the color and the form of the clouds is desirable. If, in addition to these observations, some determinations of the altitude above the horizon can be obtained for the highest point of these phenomena, by means of some instrument for angular measurement, and an accurate record of time, these data will be especially welcome.

From observatories possessing the proper apparatus, spectroscopic investigations are solicited.

In the vicinity of Berlin the next appearance of the luminous night-clouds will be especially availed of, for determinations of their altitude, by means of simultaneous photographic impressions

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made at different places. It is intended that these altitude-determinations shall be made under as great variety of atmospheric conditions as may be, in order to determine also the possible influence of the great atmospheric vortices upon the distance of the phenomena from the surface of the earth.

Description of the phenomenon. The luminous night-clouds are seen only within that portion of the evening or morning heavens which is illuminated by the twilight and separated from the night-sky by a more or less washy semicircle, the twilight-arch. When they are seen in the evening, it is when the sun is about 10° below the horizon, and they usually remain visible as long as the twilight lasts. In the morning this order is reversed. In their form and structure the luminous night-clouds much resemble ordinary cirrus-clouds, but they differ from these in some essential respects, by which they can generally be at once distinguished. For if common cirrus-clouds are within the twilight segment, when the sun is 10° or more below the horizon, they are always darker than the twilight-sky around them; while, on the other hand, the luminous night-clouds are always brighter than this sky. Moreover, the ordinary cirrus-clouds do not usually disappear, when the twilight-arch passes by them so that they are left in the night-sky; they only change their aspect in such wise that, whereas they were previously darker than the sky around them, they appear, after their entrance into the night sky, brighter than this is. But the luminous night-clouds disappear entirely so soon as the twilight-arch has moved past them, and only such portion remains visible as remains within the twilight-segment. With regard to the color of the luminous night-clouds, it should be mentioned that they glow with a white and silvery lustre, which changes toward a golden yellow in the vicinity of the horizon. And furthermore, it is worthy of notice, that the phenomenon is not manifested on every otherwise cloudless evening or morning during the season of its visibility, but occurs for the most part with intervals of from 8 to 14 days, and then usually remains visible for several successive nights. For observing it, it is requisite that the horizon in the direction of the twilight be as free as possible. Electric and gas-light generally interfere with its perceptibility.

O. JESSE.

Postscript. The luminous night-clouds have lately been seen, as I had anticipated, at the southern extremity of South America. Mr. STUBENRAUCH, meteorological observer at *Punta Arenas* has just written me that he observed the phenomenon twice in December, 1888. Furthermore, according to the same communication, it has been seen for several years by a naval officer at Beagle Channel somewhat to the southward of *Punta Arenas*. The description of the phenomenon, as given by Mr. STUBENRAUCH, leaves no doubt whatever that it is identical with that observed in Europe.

Berlin Observatory, 1889 *March* 28.

NOTICE.

This number completes the eighth volume of the *Astronomical Journal*, and the second since its reestablishment in November, 1886. While it cannot be expected that a periodical of this character can, for some years to come, be financially self-sustaining, and although the pecuniary returns do not indeed yet defray one-half of the actual outlays, still the permanent continuance of the *Journal* may be regarded as assured beyond all reasonable question.

The cordial support of almost all American astronomers, and the friendly aid of a large number in other countries, have lightened the cares and diminished the responsibilities of the Editor; and give the fullest ground for confidence that the hopes which prompted the reestablishment of the *Astronomical Journal* will be more than amply fulfilled.

The disinterested and invaluable assistance, as well as the unfailing encouragement received from our most eminent fellow-workers, calls for especial gratitude; and it would be unpardonable to omit public acknowledgement of the essential service rendered by Mr. CHANDLER, who, during the Editor's absence for nearly four months of last summer, attended to every detail of editorship and publication.

I have now the gratification of announcing that Mr. S. C. CHANDLER will hereafter be associated with me in the management; and that communications for the *Astronomical Journal* may in future be addressed to either him or the present Editor.

G.

Cambridge, Mass., 1889 *May*.

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